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Psychology
It's time to stop treating the midlife crisis like a joke

Night Sky
Light pollution is drowning out the stars

COVID
All you need to know about the new variant

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How do apps and computers 'get bugs'? →p75

FROM THE EDITOR

Everyone I know is tired. I'm tired. I bet you're tired! It feels a bit like a bug that everyone's caught. According to a YouGov survey last year, one in eight of us feels TATT, Tired All the Time, stuck in a state of constant exhaustion. Furthermore, another 25 per cent of the people surveyed said they felt tired most of the time.

So what's going on? Mobile phones, a non-stop lifestyle and, in the last few years, a daisy chain of global crises, can all share some of the blame for keeping us up at night. But more serious issues, like sleep disorders, are on the rise too. This sleeplessness adds up – it doesn't just hinder our ability to enjoy life, it's a major risk factor in a number of chronic diseases. Sleep, as the neuroscientist and author of *Why We Sleep*, Dr Matthew Walker, puts it, is like our superpower. It helps us form memories, and recovers and resets our body and brain in more ways than we understand.

Over on p66, Catherine Offord explains what we know about this looming health crisis, and shares what the sleep experts suggest you do to hit a hard reset on your sleep and reclaim your rest.

In the meantime, I strongly suggest you check out our very relaxing podcast. You can find it on your preferred podcast app, where you'll hear us interviewing scientists about some of the stories that you'll find in this issue, as well as others that never make it to the page. This month we've covered how ChatGPT is set to revolutionise education, how you can make your garden welcoming to wildlife, and how light pollution could rob future generations of the chance to see the stars.

Enjoy the issue!

Daniel Bennett

Daniel Bennett, Editor

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ON THE BBC THIS MONTH...

The Curious Cases Of Rutherford & Fry
A recent episode combines two subjects close to our hearts, aliens and Egyptology, to pose the question: could aliens have really built the pyramids? (As anyone who's watched *Stargate* knows: yes, yes they did.)
Available now on BBC Sounds

UK SPACE AGENCY

The UK's Race To Space
Is the UK about to become a global player in space? Rebecca Morelle investigates the highs and lows in our ambitions for space exploration.
Available now on BBC iPlayer

CrowdScience: Are Yoga Claims Bogus Claims?
Yoga is said to help you lose weight, improve your heart health and help you deal with the ill effects of stress, all while making you more flexible. But is there any science behind these claims? Marnie Chesterton adopts the lotus position to find out.
BBC World Service, 17 February, 8:30pm

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DR CHRISTIAN JARRET
A mid-life crisis means drastic changes: fast cars, Lycra-clad hobbies and bad haircuts. But psychologist Christian explains why it is no cause for alarm. →p38

DR HELEN PILCHER
A biologist who's covered the techniques that aim to bring lost species back from the dead, Helen explores how they could be used to save the last northern white rhinos. →p52

CATHERINE OFFORD
A reporter and editor who is passionate about medicine and science policy, Catherine digs into the nation's collective exhaustion. →p66

PETE LAWRENCE
Pete presents the practical astronomy parts on the BBC's *The Sky At Night*, where he tells you how to see wonderful sights. Who better to help you try lunar photography? →p82

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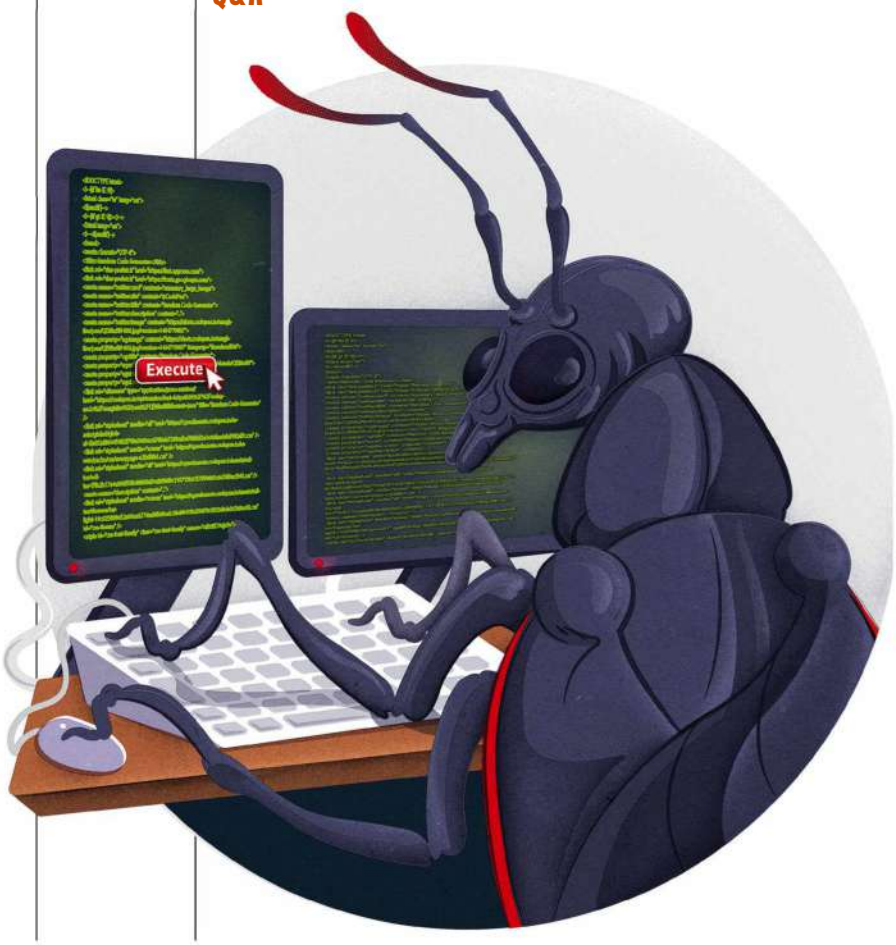

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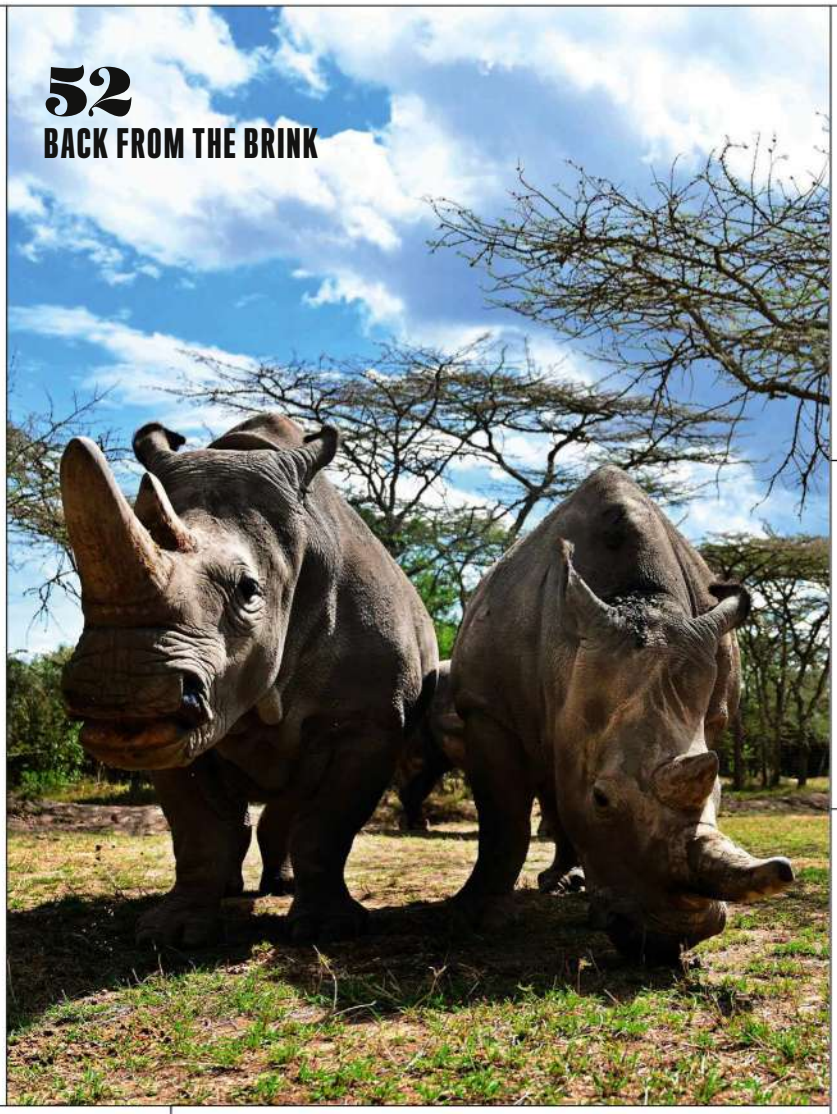

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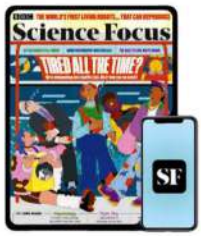

Can't wait until next month to get your fix of science and tech? Our website is packed with news, articles and Q&As to keep your brain satisfied.
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EYE OPENER

Going long

ALBULA, SWITZERLAND

"The train now arriving at platform four, five, six, seven and eight is a world record holder," is how they might announce the arrival of this locomotive as it pulls into the station.

It officially became the world's longest passenger train when it completed its 25km (15.5-mile) trip through the Swiss Alps, from Preda to Bergün, on 29 October 2022.

The train, which measures 1.9km (1.2 miles) in length, belongs to the Rhaetian Railway company and was created to commemorate the 175th anniversary of Switzerland's first railway. It's actually 25 electric Capricorn trains coupled together to form the 100-carriage record breaker and it took seven drivers and 21 technicians to ensure it completed its journey successfully.

But while it holds the record for the longest passenger train, it's by no means the longest train in the world. That title belongs to Mt Goldsworthy, a freight train operated by the Australian mining company BHP, which measures a staggering 7.24km long (4.5 miles). Good luck finding the buffet car on that.

SWISS-IMAGE.CH

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EYE OPENER

Can't see me!

AMAZON, ECUADOR

When you're a tiny insect, one of the best ways to avoid getting eaten by predators is to disguise yourself as something else. And treehoppers are masters of mimicry. There are more than 3,000 species of the bugs, many of which have evolved into fascinating shapes that resemble leaves, seeds or even faeces, to camouflage themselves in their treetop homes. This species, from the *Alchisme* genus, is pretending to be a thorn.

Treehoppers feed on plant sap, using their mouthparts to pierce a hole into stems. Some species will even form a mutually beneficial relationship with ants (the ants lick honeydew excreted by the treehoppers, and protect the bugs from hungry predators in return).

"This was the first time I had found one so close to a thorn and showing its mimicry really well," says photographer Murray Cooper. "You have to be careful not to bump the plant as they immediately hop to another one!"

MURRAY COOPER/MINDEN PICTURES

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EYE OPENER

Stacking up nicely

TEXAS, USA

The 120m-tall Starship towers over the Gulf of Mexico at SpaceX's Starbase facility in south Texas. A fully fuelled, 'wet dress rehearsal' (everything but a launch) was successfully carried out on 23 January 2023, marking a huge milestone ahead of the craft's maiden orbital flight. It was the first time a Starship (the top part) and Super Heavy booster (the bottom part) had been integrated and fully fuelled with more than 4.5 million kilograms of propellant.

Once operational, the fully reusable vehicle will overtake NASA's Space Launch System (SLS) as the most powerful rocket ever built. Powered by 33 Raptor engines, it's capable of delivering up to 150 tonnes into a low-Earth orbit and has twice the thrust of the Saturn V. The ultimate aim is to carry cargo and people beyond Earth, and bring us closer to that long-awaited colony on Mars.

Before that, however, Starship needs a successful simultaneous test-firing of all 33 of its Raptor engines and to complete an orbital test flight.

SPACEX

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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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LETTER OF THE MONTH

Even successful landings can leave a mess behind

Litter at landing sites

There are some great pictures in your magazine, especially the one showing the remains of the landing gear for NASA's Perseverance rover (New Year, p10). My first thought was, "Wow, the picture quality is fantastic!" But it quickly turned to, "Wow, what a mess!"

As an apprentice engineer, about 50 years ago, the first lesson I learnt was to never be seen doing nothing. If you've finished the job you've been given and there's nothing else to do, then pick up a brush and start sweeping. Let's hope that when the first settlers arrive on Mars sometime in the future, the job at the top of their to-do list is clear up the mess left by previous missions. It seems funny that we go to all the trouble of keeping the spacecraft super clean before they leave, only for them to create a big mess when they arrive. I wonder if there's a plan to clean up?

Keith Oldham, Lancaster

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a set of **Edifier W820NB headphones**. Whether you're listening to music, audiobooks and podcasts, or just playing games, the Edifier W820NB headphones provide exceptional audio. Featuring titanium diaphragms and 40mm dynamic drivers, they deliver richly balanced bass, mids and trebles, and also work as noise-cancelling headphones for when you want some peace and quiet. **edifier.com**

Bats are best

I was interested in your news story on bats (New Year, p29), regarding the discovery that they have a seven-octave vocal range, outstripping that of humans. They appear to be the most evolutionarily advanced of mammals: not only can they fly, but by using echolocation they can navigate their surroundings whether it's day or night, while we stumble around in the dark. Vampire bats are known to generously share their blood meals with less-successful neighbours and live in close-knit communities without apparent antagonism. They also have a remarkable cardiovascular system that allows them to hang upside-down without ill effect. But perhaps their greatest advantage is their immune system, which is far better than ours, and is able to deal with rabies, Ebola and other diseases that kill us. Bats are unlikely to dominate humans, but in terms of evolution, they're more advanced than we are.

Roger Webber, Argyll

They echolocate, they fly, they have great immune systems... jealous much?

"COMPANIES MAY NOT BE ABLE TO ANTICIPATE EVERY OUTCOME. BUT THEIR CLAIMS THAT THE OUTPUT IS SIMPLY A REFLECTION OF REALITY IS A DEFLECTION"

DR KATE DARLING, P34

Those Centaurians... no more advanced than us, apparently

NASA/JPL, GETTY IMAGES X2, PETE LAWRENCE

It's a long way to Centauri

Right now, our existing space technology is maybe capable of getting a flyweight probe to the Alpha Centauri system in about 75,000 years. Were we to send an electronic message there, it would take around four years. If they exist, the Centaurians are probably faced with the same constraints, which could explain why none of their spacecraft have been detected. And the lack of any electronic communications from them probably explains why we don't expect them to have a technologically advanced civilisation.

Kenneth Healy, Michigan, USA

The puzzle of protons

I'd just like to say how much I enjoy the columns by Dr Katie Mack. Her column on the proton was quite revolutionary (New Year, p34), with all sorts of information new to me, and presumably most other readers. Long may she continue to amaze us.

John Waterman, via email

FOLLOW THE CONVERSATION

CATCH UP ON OUR CONTRIBUTORS' TWEETS

@amybarrett31 *(Amy Arthur)*
Our bodies deserve the same care and attention as we give our houseplants. And I have never been so acutely aware of the energy needed to grow and sustain life and of how easily we can fall into bad habits, as I have been while pacing (and gardening).

@DrRadhaModgil
(Radha Modgil)
Your Sunday 'Not To Do List':

1) Worry about tomorrow – it won't change anything

2) Stay up late & ignore your need for sleep to prolong the weekend

3) Regret stuff you 'should' have done

4) Set unachievable goals for the week ahead

5) Spend time with those who don't support you

@Avertedvision *(Pete Lawrence)*
Better process of Mars and the Moon from this morning (04:57:57 UT to be precise!)

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Prof Anne-Marie Minihane, University of East Anglia

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DISCOVERIES

“I took one look at these data and I said, ‘We are dropping everything else!’”
Prof Shardha Jogee **p19**

HEALTH

WALK IT OFF

Regular short strolls stave off the bad effects of sitting down for too long **p18**

SPACE

ANCIENT GALAXIES SPOTTED

James Webb Space Telescope sees new details hiding in old galaxies **p19**

COVID

SPONGE TO THE RESCUE!

New medicine that fights COVID infections found in sea sponge **p20**

HEALTH

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Blood tests show signs of Alzheimer’s 10 years before symptoms appear **p21**

ZOOLOGY

RARE CHIMP BORN

Birth at Chester Zoo offers hope for critically endangered species **p22**

SPACE

COSMIC DOUGHNUT

Hubble Space Telescope spies a distant black hole twisting a star into a giant fluffy ring before consuming it **p23**

NASA/JPL-CALTECH

The black hole in galaxy ESO 583-G004 has been observed breaking apart a nearby star then ‘baking’ its remnants into a doughnut

PHYSICS

MINIATURE T-1000-STYLE ROBOT CAN SHIFT BETWEEN LIQUID AND SOLID STATES

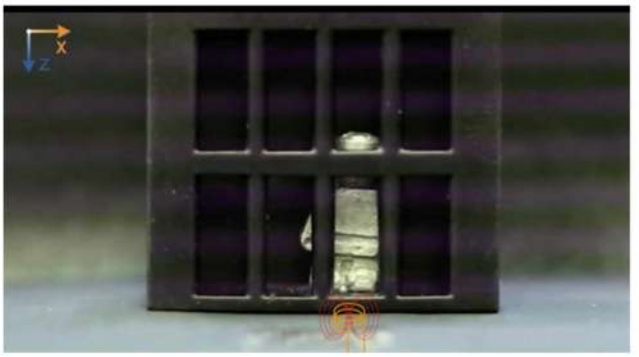
The researchers demonstrated the bot's sci-fi-like ability by making it turn into a liquid to escape from a cage

Researchers based at Carnegie Mellon University in Pennsylvania have demonstrated a robot that can melt into a liquid and then reform into its original solid state, much like the terrifying T-1000 from the movie *Terminator 2: Judgment Day*.

The robot's designers showed off its astounding capability by locking it in a cage, before having it melt into liquid, ooze through the cage's bars and then reform on the outside.

The team created the phase-shifting bot – formally referred to as a 'magnetoactive solid-liquid phase transitional machine' – by embedding magnetic particles into gallium, a metal with a very low melting point of 29.8°C.

A phase shift is the process of matter changing from one state – either solid, liquid, gas or plasma – to another. These changes occur when sufficient energy is supplied to, or lost from, the matter.



LEFT By shifting between its solid and liquid states, the phase-transitional machine (that resembles a LEGO minifigure) was able to escape through the bars of a cage

"The robot's been used as a screw by melting into a threaded socket and solidifying"

ABOVE LEFT The T-1000 featured in *Terminator 2* used its 'mimetic polyalloy' construction to disguise itself and turn its limbs into weapons

In the case of this phase-shifting bot, it can be heated into its liquid form or cooled back into its solid form through the application of an external magnetic field. The same magnetic field can also be used to move the robot around.

"The magnetic particles [embedded in the robot] have two roles," said senior researcher and mechanical engineer Prof Carmel Majidi of Carnegie Mellon University. "One is that they make the material responsive to an alternating magnetic field, so you can, through [magnetic] induction, heat up the material and cause the phase change. But the magnetic particles also give the robots the ability to move in response to the magnetic field."

Though currently in the proof-of-concept stages, the robot could have a number of applications. The researchers have already used it to remove a foreign object from a model stomach, and also as a drug delivery system. The robot's even been used to repair circuits by oozing into hard-to-reach areas and acting as solder, and as a screw by melting into a threaded socket and then solidifying.

"Future work should further explore how these robots could be used within a biomedical context," said Majidi. "What we're showing are just one-off demonstrations, proofs of concept, but more study will be required to delve into how this could actually be used for drug delivery or for removing foreign objects."

SHUTTERSTOCK, WANG AND PAN ET AL X3

HEALTH

A FIVE-MINUTE STROLL EVERY HALF AN HOUR CAN OFFSET THE ILL EFFECTS OF SITTING STILL FOR TOO LONG

Taking regular breaks in the working day can significantly reduce blood pressure

Increasing evidence suggests that sitting down too much can put our health at risk. According to the NHS, being inactive is linked to an increased risk of type 2 diabetes, some forms of cancer and early death. Due to this, its advice is to "move more, sit less". But how often should we be getting up from our chairs and for how long do we need to move?

Now, researchers based at Columbia University, New York, have an answer: taking a five-minute walking break every half an hour can offset some of the harmful effects of prolonged sitting. The team had a group of 11 participants sit in ergonomic chairs for an eight-hour stretch, rising only for bathroom breaks or a prescribed period of walking on a treadmill. The exercise periods tested were one minute of walking after every 30 minutes of sitting, one minute every 60 minutes, five minutes every 30 minutes, five minutes every 60 minutes and no walking at all.

While sitting, the participants could use their phones, or a laptop, or could read, and were given regular meals. Their blood pressure and blood sugar were periodically measured throughout the study.

High blood pressure can increase the risk of heart attacks and strokes, while large blood sugar spikes can leave us feeling lethargic and irritable. Long-term blood sugar issues can raise the risk of conditions such as kidney disease, heart disease and dementia.

The researchers found that any amount of walking reduced blood pressure by 4-5mmHg compared to sitting all day – a significant reduction, as ideal blood pressure is usually considered to be between 90/60mmHg and 120/80mmHg.

"This is a sizeable decrease, comparable to the reduction you would expect from exercising daily for six months," said study leader Keith Diaz, associate professor of behavioural medicine at Columbia University.

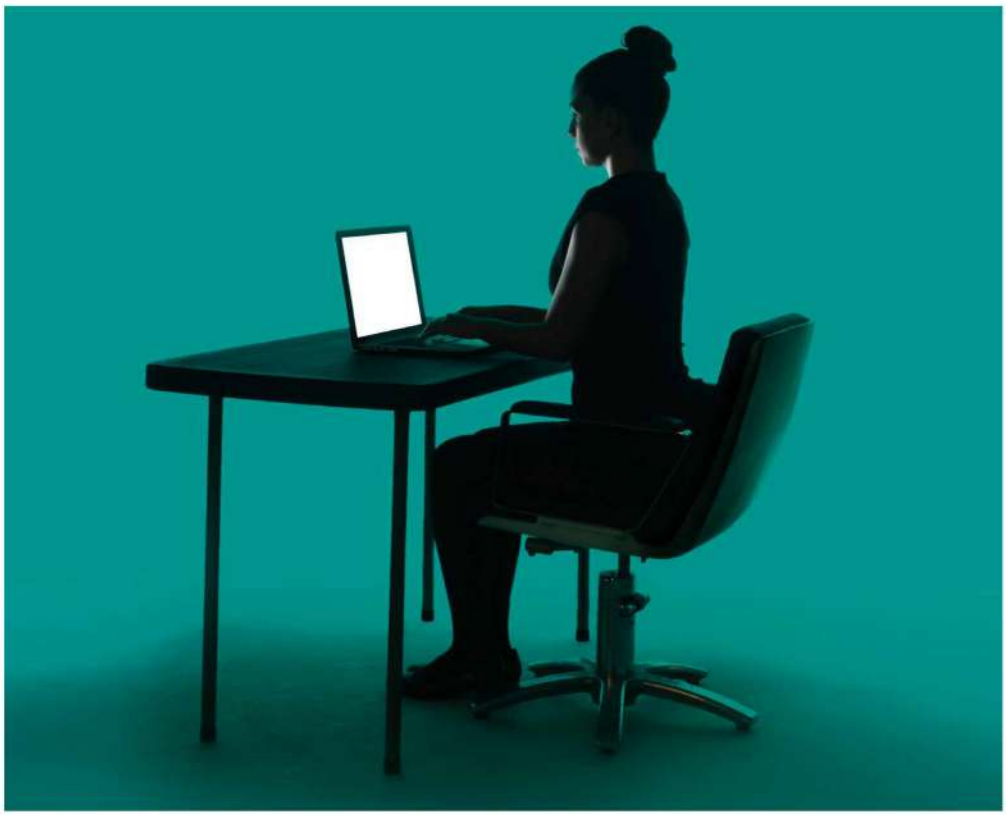
Additionally, walking for five minutes every 30 minutes reduced blood sugar spikes after meals by more than 50 per cent. Walking for one minute every 30 minutes also led to a small reduction in blood sugar spikes. Walking every 60 minutes, whether for one minute or five, had no effect.

In addition, the scientists found that all of the walking regimens, except for one minute of walking per hour, led to significant improvements in mood and decreased fatigue.

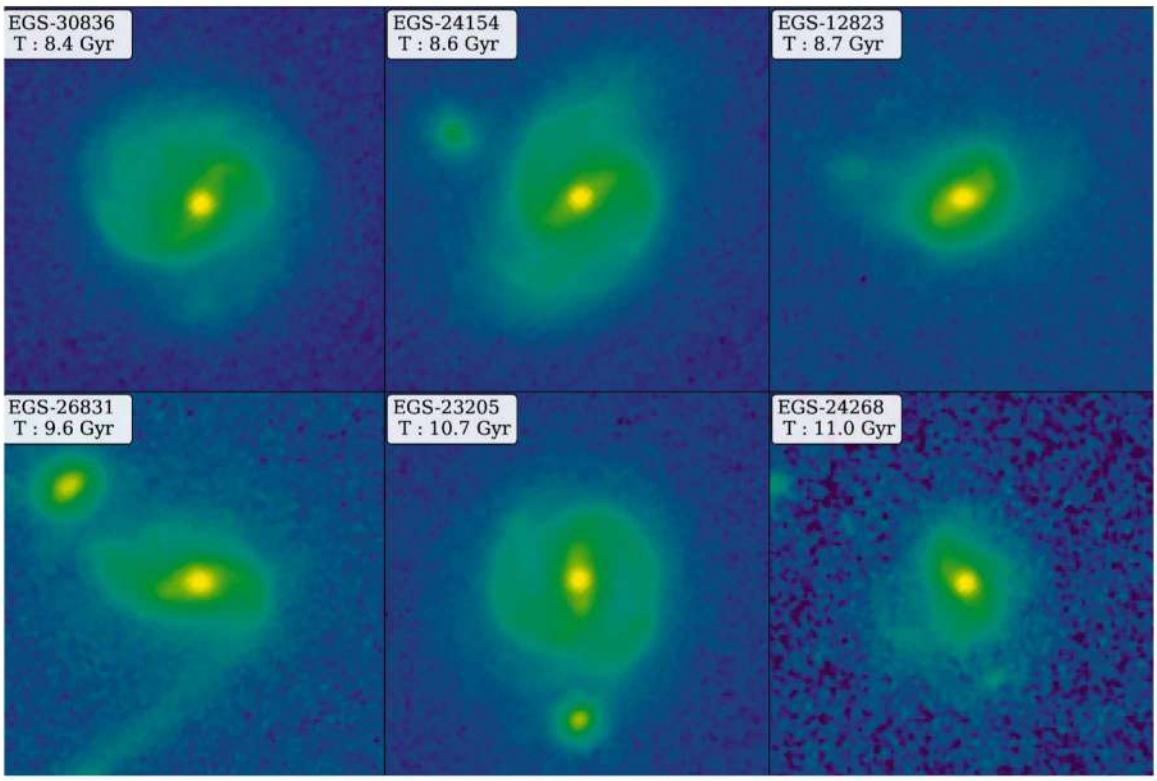
"What we know now is that for optimal health, you need to move regularly at work, in addition to a daily exercise routine," said Diaz. "While that may sound impractical, our findings show that even small amounts of walking spread through the workday can significantly lower your risk of heart disease and other chronic illnesses."

BELOW Your body will really thank you if you can get up and go for a short walk every half an hour

RIGHT Six barred galaxies imaged by the JWST. The labels show the lookback time of each galaxy, ranging from 8.4 to 11 billion years ago (Gyr)



NASA/CEERS/UNIVERSITY OF TEXAS AT AUSTIN, GETTY IMAGES



6.5M
The size of the JWST's primary mirror – almost three times that of the Hubble Space Telescope.

$10BN
The cost to build the JWST. That's roughly four times the amount Elon Musk, one of the world's richest people, earns in a year.

13.6 BILLION YEARS
The JWST can image events that happened as long as 13.6 billion years ago, just a few hundred million years after the Big Bang.

SPACE

JAMES WEBB SPACE TELESCOPE SPOTS GALAXIES LIKE OUR OWN IN THE EARLY UNIVERSE

Their discovery means a rethink of a theories of how galaxies evolve

NASA's James Webb Space Telescope (JWST) has come up with the goods again. Images released by the space agency show some of the oldest barred galaxies ever discovered. The galaxies feature so-called stellar bars – elongated bands of stars that stretch from the galaxies' centres into their outer discs, like those seen in the Milky Way. Two of the six date back to a time when the Universe was just 3.4 billion years old, one-quarter of its current age.

One of the galaxies, EGS-23205, was previously imaged by the Hubble Space Telescope but the resolution was not high enough for astronomers to make out its spiral shape and prominent stellar bar. These fine details are clearly visible in the higher resolution images produced by the JWST. The structure of a second galaxy, EGS-24268, is also distinguishable.

Both barred galaxies date back to around 11 billion years ago, making them older than any previously discovered, and were found in data collected by the JWST's Cosmic Evolution Early Release Science Survey (CEERS). Four other barred galaxies from more than eight billion years ago were also found in the data.

"I took one look at these data, and I said, 'We are dropping everything else!'" said the study's co-author Prof Shardha Jogee, from the University of Texas at Austin.

"The bars hardly visible in Hubble data just popped out in the JWST image, showing the tremendous power of the JWST to see the underlying structure in galaxies."

Stellar bars play a central role in the evolution of galaxies by transporting gas from the outer regions to the centre. This gas is then rapidly converted into new stars at a rate between 10 and 100 times faster than in the rest of the galaxy. It can also help to fuel the growth of the supermassive black holes found at galaxies' centres.

Finding barred galaxies in the early Universe also raises questions about current theories of galaxy evolution. The team now plans to test different models of galactic evolution to explain their new findings.

"This discovery of early bars means galaxy evolution models now have a new pathway via bars to accelerate the production of new stars at early epochs," said Jogee.

COVID

POTENTIAL NEW COVID-FIGHTING MEDICINE IDENTIFIED IN SEA SPONGES AND BACTERIA

The newly-discovered substances are effective against the Delta variant and several Omicron variants

Three compounds that effectively fight COVID-19 infection in human cells have been discovered by researchers based at the University of British Columbia.

One, alotaketal C, was derived from a sea sponge collected in Howe Sound, British Columbia, while the others, bafilomycin D and holyrine A, were derived from marine bacteria found in Barkley Sound, British Columbia, and Newfoundland.

The discovery suggests that there could be a wealth of COVID-19 medicines waiting to be discovered from natural sources.

The team made the discovery after investigating the COVID-fighting properties of more than 350 compounds derived from natural sources, including plants, fungi and sea sponges, collected from around the world over the last 40 years.

They bathed human lung cells in solutions made from each of the compounds, then exposed them to a version of the SARS-CoV-2 virus that causes cells to glow fluorescent green when infected.

They found that 26 of the compounds completely reduced viral infection in the cells and that three of them were still able to do so in very small doses.

Further testing showed that those three compounds were effective against the Delta variant and several Omicron variants. This is important in the continuing fight against COVID-19, as many current treatments are less effective against Omicron variants.

"The advantage of these compounds is that they are targeting the [infected] cells, rather than the virus, blocking the virus from replicating and helping the cell to recover," said co-first author Dr Jimena Pérez-Vargas, a research associate in the department of microbiology and immunology.

DAVID FENWICK/APHOTOMARINE.COM, ALAMY

ABOVE Sea sponges like these could help fight COVID-19

RIGHT Beta-amyloid (brown tangles) forming between brain cells

"Human cells evolve more slowly than viruses, so these compounds could work against future variants [of COVID-19] and other viruses such as influenza if they use the same mechanisms," she added.

The researchers now plan to test the compounds in animal models.

"Our research is also paving the way for large-scale testing of natural product medicines that can block infection associated with other respiratory viruses of great concern in Canada and around the world, such as influenza A and RSV," said senior author Dr François Jean, associate professor in the department of microbiology and immunology.

HEALTH

BLOOD TEST PREDICTS ALZHEIMER'S DISEASE 10 YEARS BEFORE SYMPTOMS APPEAR

The presence of a substance released by brain cells could be an early warning sign for the condition

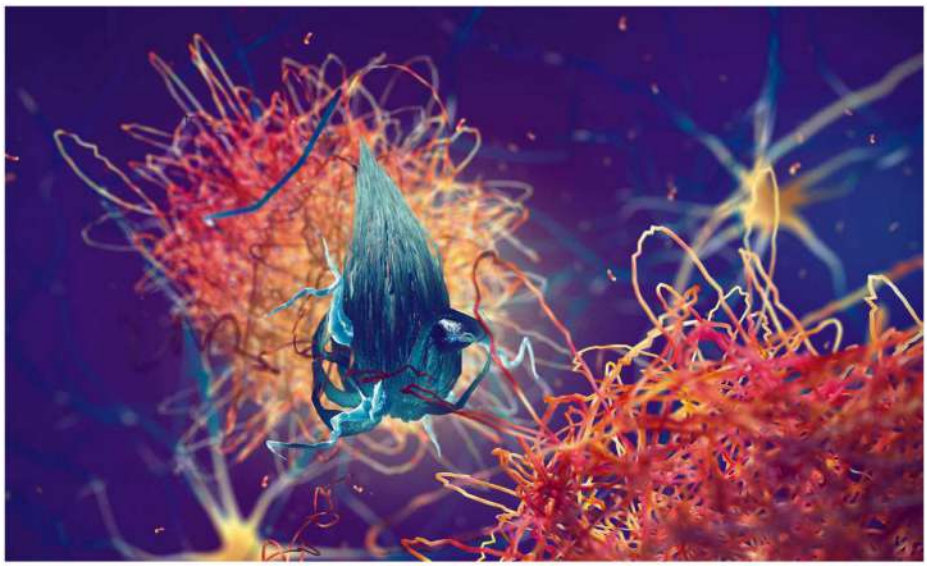
The presence of a specific biomarker in the blood may be an early indicator of Alzheimer's disease, researchers from Sweden's Karolinska Institutet have found. The discovery could lead to earlier diagnosis of the condition via blood tests, and increase the chance of slowing down its progression.

Alzheimer's disease is responsible for around 60 to 70 per cent of all dementia cases. It is caused by beta-amyloid and tau proteins building up in the brain and damaging nerve cells. These build-ups can begin up to 25 years before they lead to noticeable symptoms such as memory loss and issues with speech.

The team analysed blood plasma samples from 75 patients, 33 that carried a genetic mutation that predisposes them to develop a rare inherited form of Alzheimer's and 42 without the mutation.

They found that an increase in glial fibrillary acidic protein (GFAP) in the blood was a potential early warning sign for those that went on to develop Alzheimer's. GFAP is produced by cells called astrocytes in the brain and spinal cord. The levels of GFAP was seen to increase around 10 years before the emergence of the first symptoms.

"Our results suggest that GFAP, a presumed biomarker for activated immune cells in the brain, reflects changes in the brain due to Alzheimer's disease that occur before the accumulation of tau protein and measurable neuronal damage," said lead researcher Charlotte Johansson, doctoral student at the department of neurobiology, care sciences and society, Karolinska Institutet, Sweden. "In the future it could be used as a non-invasive biomarker for the early activation of immune cells such as astrocytes in the central nervous system, which can be valuable to the development of new drugs and to the diagnostics of cognitive diseases."



ZOOLOGY

CHESTER ZOO CELEBRATES BIRTH OF WORLD'S RAREST CHIMPANZEE

The new birth offers hope that the critically endangered animals could have a brighter future

Chester Zoo has announced the birth of a critically endangered western chimpanzee.

The male chimp is in good health and is spending the first few weeks of his life bonding with his mother, ZeeZee, and the other members of the zoo's 22-strong troop.

He will be named after a rock or pop star, like three other baby chimpanzees previously born at the zoo – Dylan (Bob), Alice (Cooper) and Annie (Lennox).

"We're incredibly proud to see a precious new baby in the chimpanzee troop. Mum ZeeZee and her new arrival instantly bonded and she's been doing a great job of cradling him closely and caring for him," said Andrew Lenihan, team manager of the primates section at Chester Zoo.

"A birth always creates a lot of excitement in the group and raising a youngster soon becomes a real extended family affair.

"You'll often see the new baby being passed between other females who want to lend a helping hand and give ZeeZee some well-deserved rest, and that's exactly what her daughter, Stevie, is doing with her new brother. It looks as though she's taken a real shine to him, which is great to see."

CHIMPANZEE FACTS

Chimpanzees are one of the planet's five species of great apes. The others are gorillas, orangutans, bonobos and humans.

Birth rates are incredibly low. A mature female will generally only give birth to a single baby chimp, or sometimes twin babies, once every five to six years.

Like humans, chimps are omnivores and eat everything from leaves and flowers, to insects, birds' eggs and even monkeys.

Western chimpanzees are a medium-sized subspecies of the common chimpanzee. They grow to around a metre in length from head to rump and weigh as much as 45kg. They can live for more than 40 years and are notable for their unusual behaviours. These include the use of spears to hunt and catch prey, and a strange habit of throwing large rocks against trees or into hollow tree stumps.

They are the first subspecies of chimpanzee to be declared critically endangered by the International Union for the Conservation of Nature (IUCN). It is estimated that there are just 18,000 individuals left, living from Senegal to Ghana in West Africa. Previous populations in Benin, Burkina Faso and Togo are now extinct due to habitat loss.

"In the last 25 years alone the world has lost 80 per cent of its western chimpanzee population, so the arrival of a healthy baby here at Chester offers us real hope that we can help turn things around for this species," said Mike Jordan, animal and plant director at Chester Zoo.

CHESTER ZOO, NASA/ESA/LEAH HUSTAK/STSCI

SPACE

HUBBLE SPOTS BLACK HOLE TWISTING A STAR INTO A DOUGHNUT SHAPE, THEN CHOWING DOWN ON IT

The star strayed too close and was ripped apart by the black hole's immense gravitational forces

Just call it the Homer Simpson of black holes. Astronomers using NASA's Hubble Space Telescope have observed a black hole twisting a nearby star into a doughnut shape before consuming it.

The violent cosmic occurrence is an example of a tidal disruption event – an astronomical phenomenon that occurs when a star strays close enough to a black hole to be ripped apart by its immense gravitational forces. After the star has been ripped apart, the black hole then devours the resulting gas and debris while belching out intense radiation.

Named AT2022dsb, the event is occurring nearly 300 million light-years away from Earth at the centre of the galaxy ESO 583-G004. It was first spotted on 1 March 2022 by the All-Sky Automated Survey for Supernovae (ASAS-SN), a network of ground-based telescopes that scour the sky looking for violent events.

The astronomers then used Hubble's powerful ultraviolet imaging capabilities to study the event in fine detail as it unfolded.

"Typically, these events are hard to observe. You get maybe a few observations at the beginning of the disruption when it's really bright. Our programme is different in that it is designed to look at a few tidal events over a year to see what happens," said co-researcher Peter Maksym of the Harvard and Smithsonian Center for Astrophysics, in Cambridge, Massachusetts.

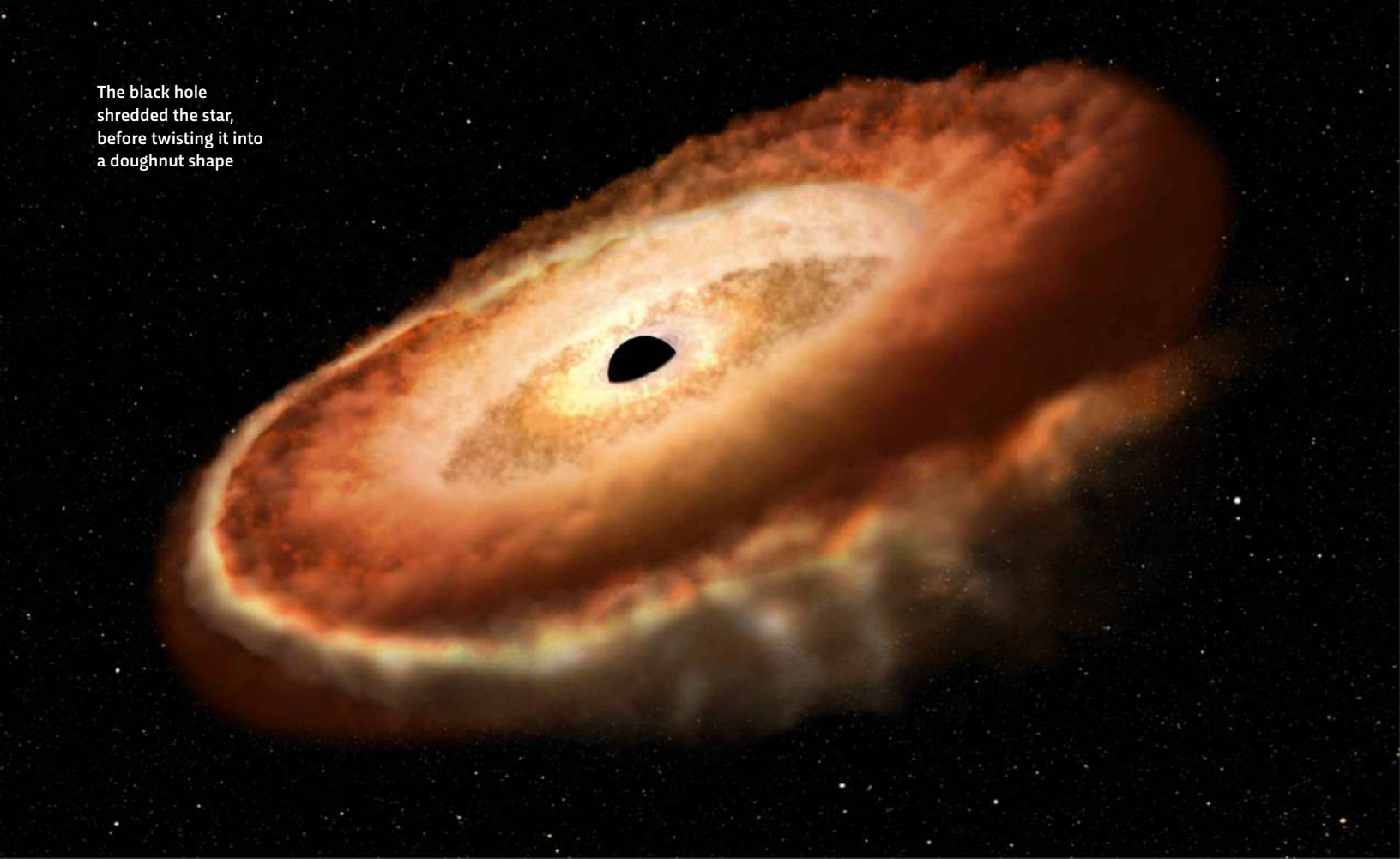
"We saw this early enough that we could observe it at these very intense black hole accretion stages. We saw the accretion rate drop as it turned to a trickle over time."

After studying the Hubble data, the researchers concluded that the remains of the star have formed a doughnut-shaped ring of gas the size of the Solar System that is encircling the black hole as it is sucked in.

The researchers hope that further study of the event, and others like it, will help them learn more about the life cycle of black holes.

"We really are still getting our heads around the event. You shred the star and then it's got this material that's making its way into the black hole," said Maksym.

"So, you've got models where you think you know what is going on, and then you've got what you actually see. This is an exciting place for scientists to be: right at the interface of the known and the unknown."



The black hole shredded the star, before twisting it into a doughnut shape

PRIMER

LIGHT POLLUTION

Brightly illuminated urban areas are increasingly obscuring our view of the night sky, making life difficult for us, astronomers and animals

The brightness of the night sky has been increasing by 7 to 10 per cent a year for the last decade, according to a study carried out by the Globe at Night project. This citizen-science campaign involved more than 50,000 observations from volunteers around the world.

The problem, according to the report, is 'skyglow' – artificial light that keeps the sky in twilight until long after the Sun has set.

We spoke to Dr Greg Brown, an astronomer based at the Royal Observatory Greenwich, about what this trend means for laypeople, astronomers and the natural world, and if there's anything we can do to reverse it.

HOW BAD IS THE LIGHT POLLUTION SITUATION? ARE WE LOOKING AT A POTENTIAL SCENARIO WHERE FUTURE GENERATIONS WON'T BE ABLE TO ENJOY LOOKING AT THE STARS?

It's a great shame that a lot of people are denied a view of the night sky. In the planetarium that we run at the Royal Observatory, we often start our shows with an estimate of the current light pollution around London. Even in our relatively dark site in the middle of Greenwich Park, we still have to deal with Canary Wharf and the main parts of the city around us.

When we compare what we can see to what the night sky would look like from a dark-sky site, the difference is massive. There's absolutely no doubt that light pollution is going to have an impact on our appreciation of the night sky.

The brightest objects in the sky [such as planets] are going to be visible beyond any reasonable level of light pollution that we could ever reach. But the fainter objects – the array of stars in the Milky Way, for example – are already basically impossible to see from suburban areas, let alone city centres. So, yes, light pollution is very much hampering the ability of the average person to be able to explore the cosmos.

HOW DO WE GO ABOUT MEASURING THE AMOUNT OF LIGHT POLLUTION?

With some difficulty. A lot of the past studies have been carried out using satellites, which are great for analysing red light, but struggle somewhat with blue light. This is a problem, as modern light pollution tends to be blue light since we started replacing sodium lamps with LEDs in street lighting. So a lot of studies nowadays have to be done from the ground in order to make up for that. That's where the citizen science angle comes from in the Globe at Night project. There simply aren't enough scientists studying this sort of thing around the world, so there has to be a certain amount of involvement from the general public to make up that deficit.

WHEN DID THIS TREND START?

Light pollution has become an increasing problem since the 1970s. It has been accelerated by the expansion of cities and urban areas, as people have relocated from rural areas. It was thought that switching over to LED light would potentially be a way to help with the problem, because more efficient lighting means that you need fewer lights. But there's also the reverse argument, which is that more efficient lighting means you can get away with having more lights for the same amount of power, so actually you make the problem worse.

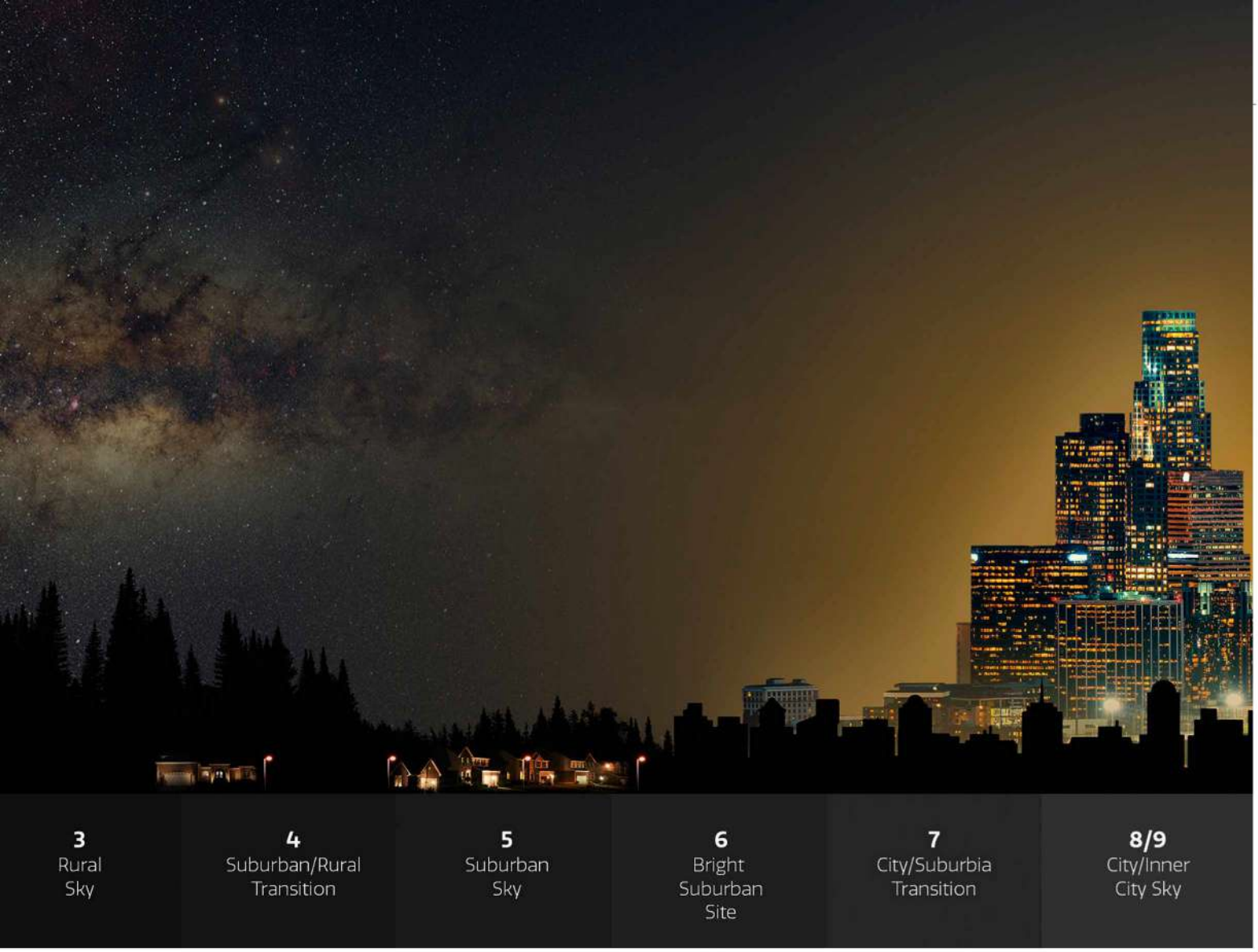
NOIRLAB/NSF/AURA/P MARENFELD, NATIONAL MARITIME MUSEUM GREENWICH

HOW MUCH DOES LIGHT POLLUTION AFFECT PROFESSIONAL ASTRONOMY?

When we're talking about professional astronomy, a lot of the observations are done from specifically chosen dark-sky sites. So we're talking about relatively unpopulated regions of the world, such as the Atacama Desert in Chile or mountains in the Canary Islands. The effect of light pollution is not so big in those places because they're so far away from cities. That's one of the reasons why they've been chosen.

That said, not all observatories are placed well away from sources of light pollution and there are issues that go beyond the light that we're putting up into the sky from the ground.

Likewise, there are, of course, issues with the increasing number of satellites that are contaminating images captured by professional observatories around the world, which, while only



tangentially related, are nonetheless light-pollution issues.

CAN LIGHT POLLUTION HAVE AN EFFECT ON OUR HEALTH?

Absolutely. As humans we're used to being awake during the day and asleep at night. The more light we introduce into our night-time skies, the harder it is for our bodies and our body clocks to determine what time it actually is. This leads to insomnia and the issues that come from that – tiredness, fatigue and poor mental health. [For more on the health problems associated with disrupted sleep, turn to p66.]

It's not just a human issue either. Wildlife suffers a great deal from the increase in light pollution. The cycle of predation and prey, for example, has, in the past, been based on the light of the Moon, because most predators need light to be able to hunt. But if every night is as lit up as though there were a full Moon, then predators can constantly prey on the various other animals out there. That can be a serious problem for the diversity and balance of the biosphere.

IS THERE ANYTHING WE CAN DO TO SLOW THIS TREND DOWN?

Certainly there is a need for careful planning when it comes to the use of lights, specifically street lights and lights in city centres. A lot of it is going to come down to where the light is directed. Of course, lighting is important; no one's denying that the streets need to be lit. The question is whether they need to be lit all the time and in the way they're currently being lit. Is there a way to be able to have the lights come on at specific times, such as when they're actually needed by an individual nearby? Is there a way of directing more, or all, of that light downwards, as the light that's going upwards is useless – it's not helping anyone down on the ground.

Anything that increases street lamps' efficiency by directing all of that light down onto the ground not only helps with light pollution, but it also helps fulfil the specific purpose of those lights in the first place.

IS THERE ANYTHING INDIVIDUALS CAN DO TO HELP WITH THIS SITUATION?

Ensure that you're not overusing lights externally. If you have lights in your garden or your driveway, hook them up to motion sensors or only have them on at times when you actually need them. Also, going for more directional light – light that's being directed downwards rather than upwards or in every direction – can very much reduce the amount of light pollution that you're generating.

DR GREG BROWN
Greg is an astronomer and science communicator based at the Royal Observatory Greenwich.

SPACE

RADIO TELESCOPES CAPTURE THE REMNANTS OF DEAD STARS HIDDEN THROUGHOUT THE MILKY WAY

This image was produced as part of a project that aims to produce a near-complete map of the Galaxy

The bright, bubbly blobs seen in this image are supernova remnants – clouds of hot gas and debris that are left behind after the dramatic explosion that occurs at the end of a star's life. Theoretical models predict that there should be far more of them scattered throughout the Milky Way than astronomers have so far been able to observe.

However, this new image, produced using data collected by the Australian Square Kilometre Array Pathfinder (ASKAP) and Parkes Observatory's radio telescopes, also in Australia, has uncovered more than a dozen supernova remnants that were previously unknown. This suggests there are many more hiding in plain sight elsewhere in the Galaxy.

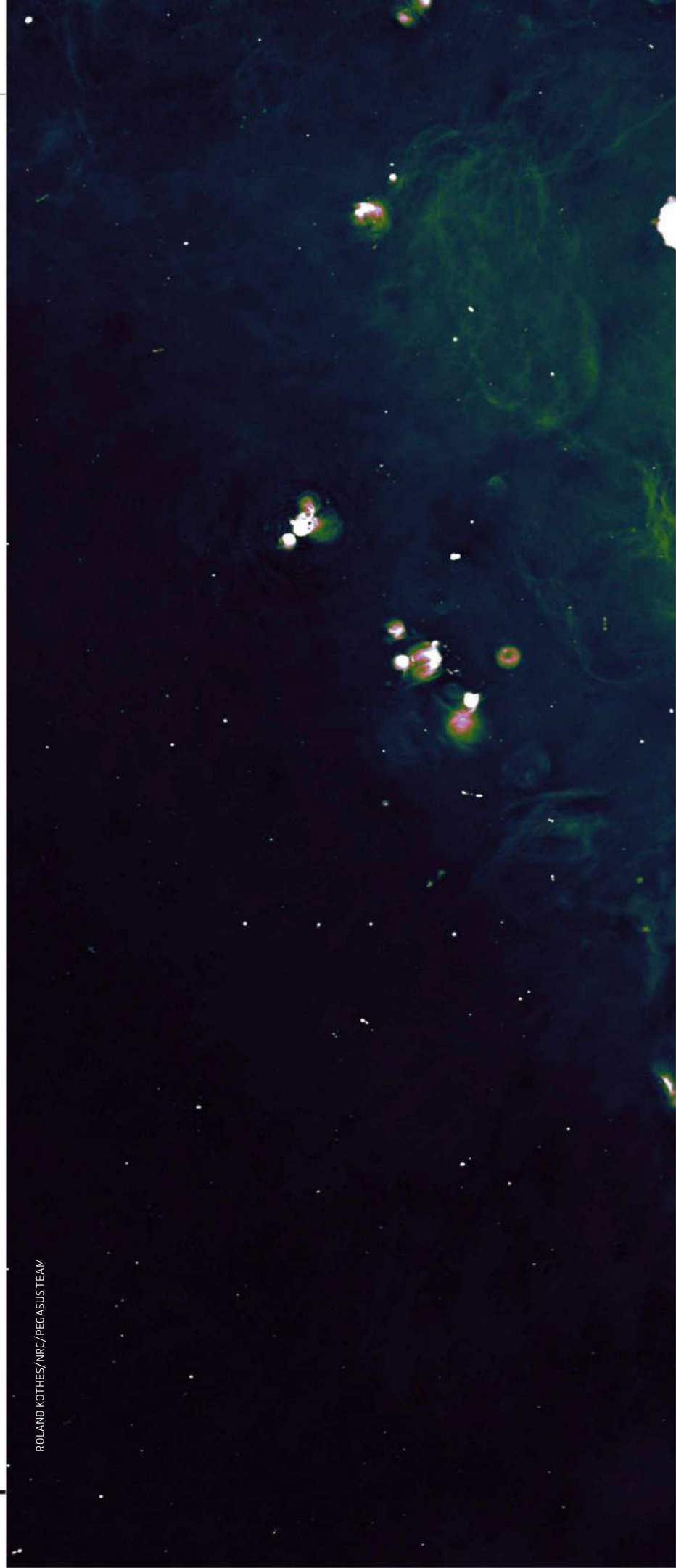
The image was produced as part of a collaboration between the Australia National Science Agency's Evolutionary Map of the Universe (EMU) project and the PEGASUS radio telescope survey, which is led by Italy's National Institute for Astrophysics.

"This new picture showcases a region of the Milky Way, only visible to radio telescopes, where we can see extended emission associated with hydrogen gas filling the space between dying stars, related to the birth of new stars, and hot bubbles of gas called supernova remnants," said Prof Andrew Hopkins, lead scientist of the EMU project. "Over 20 new possible supernova remnants have been discovered as a result of combining these images, where only seven were previously known."

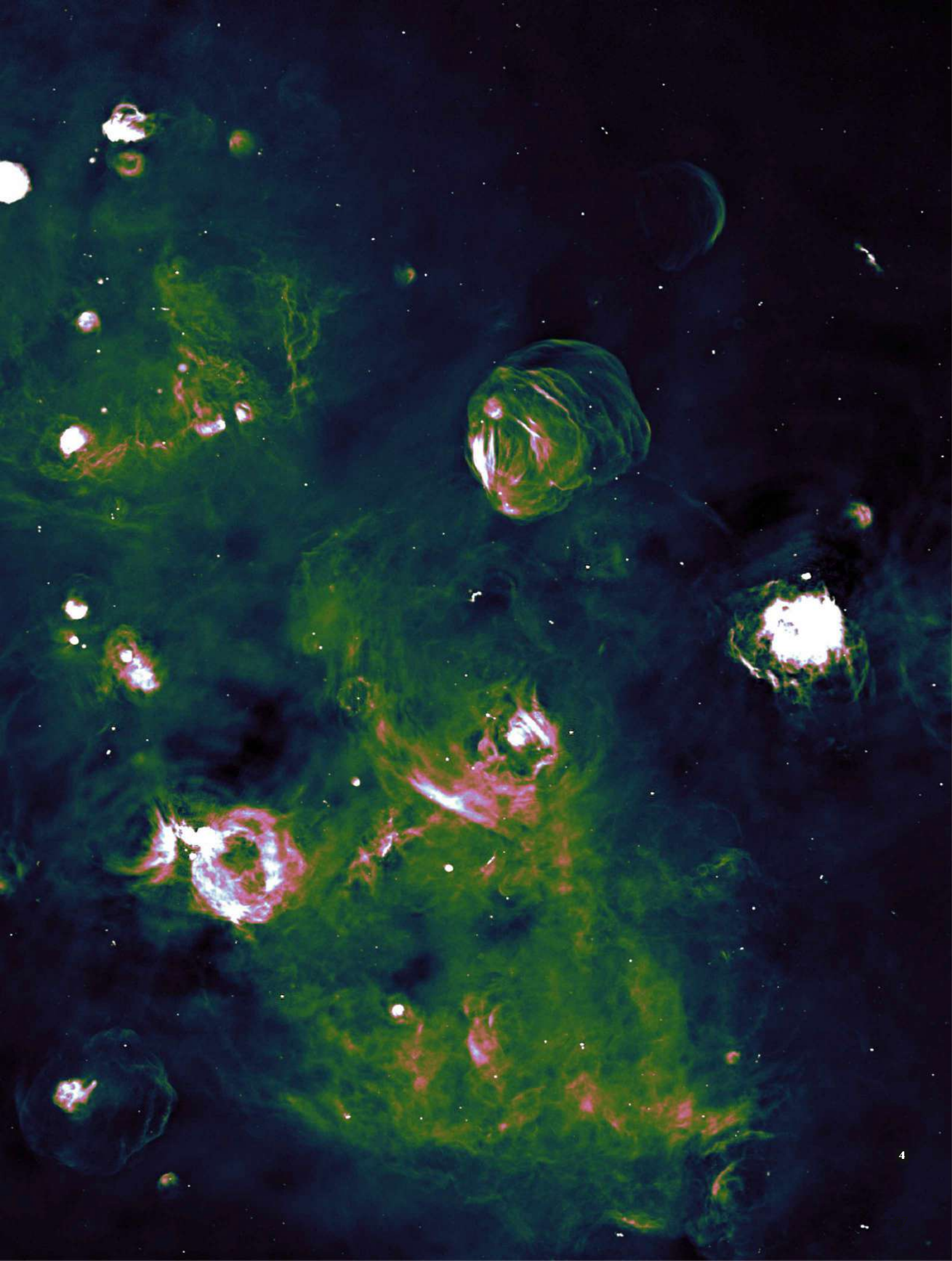
The researchers were able to map a region covering roughly 1 per cent of the galactic plane of the Milky Way. But this is just the start.

"The eventual results will be an unprecedented view of almost the entire Milky Way, about 100 times larger than this initial image, but achieving the same level of detail and sensitivity," said Hopkins.

"It is estimated that there may be about 1,500 more supernova remnants in the Galaxy that astronomers haven't discovered yet. Finding the missing remnants will help us unlock more of an understanding of our Galaxy and its history."



ROLAND KOTHES/NRC/PEGASUS TEAM

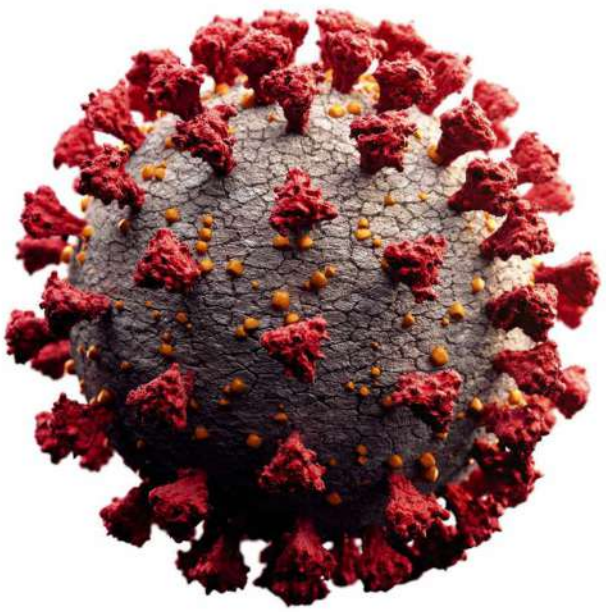


THE FUTURE'S BRIGHT...

As a remedy for all the bad news out there, let us prescribe you a small dose of feel-good science. Each issue, we'll give you a rundown of the latest breakthroughs that aim to solve humanity's biggest problems. From therapies that can extend the lives of dogs with terminal cancer to fairy-like pollination robots, here you'll find many reasons to feel hopeful for our future...

TEST CAN FISH FOR VIRUSES USING DNA AS BAIT

Researchers at the University of Cambridge have developed a test that uses DNA 'nanobait' to detect several common respiratory viruses – including influenza, rhinovirus, RSV and COVID-19 – at the same time. The method is incredibly fast, returning results in less than one hour. For comparison, the PCR tests commonly used for detecting coronavirus take several hours to return their results. The test uses strands of DNA 'bait' that can be manipulated to fish for specific molecules found in target viruses. Thanks to this flexibility, the test can be programmed to identify viral variants, including variants of the SARS-CoV-2 virus, like Omicron or Kraken (read more about Kraken on p36).

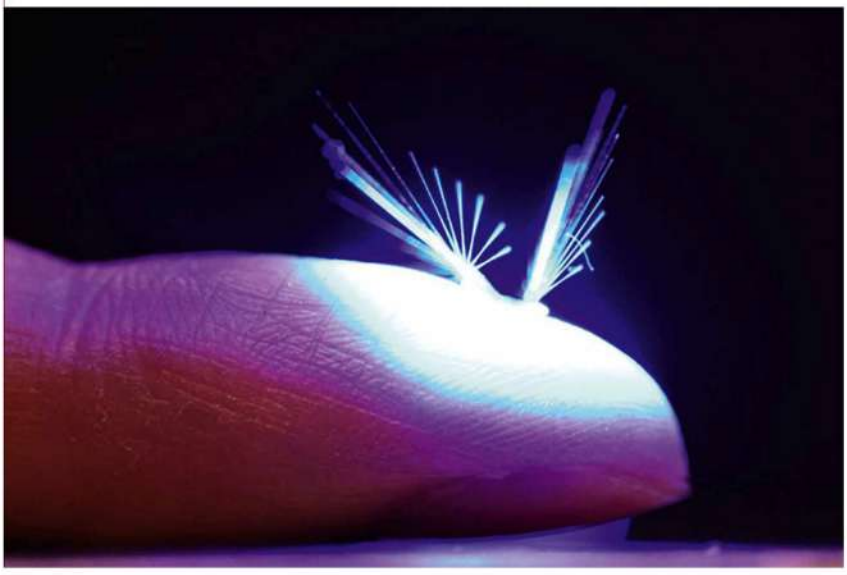


YEARS TO GO

25

FAIRY-LIKE ROBOT COULD HELP POLLINATE PLANTS

Researchers at Tampere University in Finland have created tiny robots that could one day be used to pollinate plants and flowers. Dubbed FAIRY, the bot weighs just 1.2mg, making it light enough to float on the wind. Its structure, which resembles a dandelion seed, opens and closes when stimulated by a light source such as an LED, allowing researchers to direct its flight by adjusting its shape to catch the wind. In future, millions of the bots carrying pollen could be released into the wind and then steered by light toward trees in need of pollination, the researchers say.



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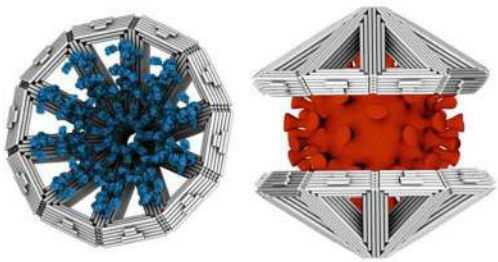
GETTY IMAGES X5, JIANFENG YANG/TAMPERE UNIVERSITY, MONFERRER ET AL

INJECTABLE BIOMATERIAL REPAIRS DAMAGE CAUSED BY HEART ATTACKS

There are currently no established treatments for repairing damage to heart tissue caused by heart attacks. But a promising new treatment may be on the way. Researchers at the University of California have developed an injectable hydrogel that can begin rebuilding heart tissue immediately after a heart attack. Once injected, the gel forms a scaffold in damaged areas of the heart, encouraging new cell growth and repair. The method has proven effective in both rodent and large animal models, and human trials could start within one to two years, the researchers say.

'ORIGAMI' DNA CAGES COULD PROTECT CELLS FROM FLU AND CORONAVIRUS

Physicists at the Technical University of Munich have created 'origami' cages from DNA that can capture viruses, to prevent them from infecting cells. The team used a combination of DNA taken from bacteriophages (a type of virus) and synthetic DNA to create two-dimensional LEGO-style building blocks, then used them to build bigger 'origami' structures that were shaped to capture the viruses. Next, they coated the cages with chemicals that bind to viruses, before letting them loose on a population of live viruses. The traps were effective in capturing several viruses, including **Zika, influenza and SARS-CoV-2. The team now plans to test the traps in animal models.**



MAGNETIC COATING REMOVES 'FOREVER CHEMICALS' FROM WATER

PFAs are long-lasting, difficult-to-break-down substances used in everything from fire retardants and non-stick pan coatings to pizza boxes and cosmetics. They are often known as 'forever chemicals', as they persist in the environment for a long time. This is not good as they have been linked to health issues including stunted growth, falling fertility rates and some forms of cancer. Now, researchers at the University of Queensland have developed a magnetic substance that could help remove PFAs from water supplies. When added to water, the compound – a so-called magnetic fluorinated polymer sorbent – coats any PFAs that are present, making them easy to remove with magnets.

10

ULTRASOUND 'TORNADOES' BREAK DOWN BLOOD CLOTS IN THE BRAIN

Blood clots in the brain may be removed quickly and safely using ultrasound, a technique developed by a team at North Carolina State University promises. The method uses an ultrasound transducer that can be inserted into the brain via a catheter to create a forward-facing tornado-like sound wave that breaks down the clot. So far, the researchers have found success in proof-of-concept tests, using a 3D-printed model filled with cow's blood. The technique was able to break down the clot in as little as 30 minutes, making it much faster than the 15 hours taken by current methods.

STEM CELL THERAPY EXTENDS THE LIVES OF DOGS WITH TERMINAL CANCER

Cancer is the leading cause of death in dogs. Despite significant advances in cancer treatments for humans over the last few decades, effective therapies for animals remain few and far between. Now, researchers from the National University of Singapore hope to change this after developing a promising new treatment using stem cells. The team modified Mesenchymal Stem Cells (MSCs), cells that are able to seek out cancerous tumours, to deliver high concentrations of the cancer-killing drug 5-fluorouracil directly to tumours. After three to eight weeks of treatment, 56 out of 65 dogs given the therapy showed significant improvements, with two remaining cancer-free for at least 30 months.

0

COMMENT

SMASHING ATOMS TO CREATE ENERGY IS A TRUE MARVEL OF NATURE

The strange science that underpins nuclear fusion

In December, the US Department of Energy made headlines worldwide with a fusion power breakthrough: for the first time, they created a reaction that produced more energy than the laser power that ignited it. While this was a major step forward, the energy to run the lasers was still a factor of 100 more than the energy produced by the reaction, so there's a lot of work yet to be done. But it brings up some interesting questions: how does fusion power even work, and what does all of this have to do with the life and death of stars?

If you're familiar with the basics of nuclear power and nuclear weapons, you might notice an apparent contradiction. Nuclear power plants and atomic bombs are both based on splitting atomic nuclei to produce power (fission), whereas fusion and hydrogen bombs work on the power you get by sticking nuclei together. How can both be possible? It has to do with the weird clinginess of atomic nuclei, and how that clinginess depends on how many protons and neutrons the atom has.

Let's start with the nuclear reaction that powers the Sun: hydrogen fusing into helium. A neutral hydrogen atom is a proton with an electron bound to it. Newborn stars are mostly hydrogen nuclei (just protons), with some helium nuclei, electrons, and a trace of other elements bouncing around. Because protons are all positively charged, they electrically repel each other, but with enough heat and pressure they will sometimes smack together. When they do, they start to interact with the strong nuclear force, and that's when everything changes. At those close distances, the strong force is stronger than electric repulsion, so two protons smashed into extremely close quarters attract.

DR KATIE MACK
(@AstroKatie)
Katie is a theoretical astrophysicist. She currently holds the position of Hawking Chair in Cosmology and Science Communication at the Perimeter Institute for Theoretical Physics.

Those smashed-together protons in the core of a star go through a few stages of transmutation before becoming helium, but the key is that the larger nuclei are more tightly bound than the smaller ones. You can think of it like clinginess. Generally speaking, elements lighter than iron get clingier as they get heavier, and when you fuse less clingy nuclei into more clingy nuclei, you get energy out. Imagine a slinky on a flight of stairs. You have to give the slinky a push to get it started, but once you do, it gains energy as it descends and can keep going as long as the stairs keep going down.

This is why fusion power is possible in principle: if you can get a reaction started and keep it going, you can create a system in which hydrogen is transformed into helium and energy is released. Hydrogen bombs work on the same principle. In stars, fusion is responsible for creating some of the most common elements on Earth. When a massive star converts all the hydrogen it can, it moves up the periodic table, creating concentric shells for helium, carbon, neon, oxygen, and silicon fusion. For all these elements, adding more protons increases the clinginess of the nucleus, and so energy is produced in the process. But something changes when you get to iron, and it's catastrophic.

Iron is the clingiest of all the nuclei that are abundant in stars. (Technically, there's a form of nickel that is more tightly bound, but it's rarely produced in stars.) That means you can get energy by fusing smaller nuclei to create iron, but if you try to add more protons, you'll end up with something less tightly bound, so the process will take rather than give energy. Iron is the atom at the bottom of the staircase, with stairs leading up to hydrogen on one side and to the heaviest elements on the other. The consequence for a star is that once it has a core full of iron, fusion no longer works there, and there's no more energy being produced to keep the star from collapsing on itself. At that point, the star explodes in a supernova, creating either a fantastically dense neutron star or a black hole. The explosion itself pumps energy into the stellar debris, which can create heavier elements, like throwing the slinky up the stairs.

On the heavy side of the 'iron peak' of clinginess, heavier elements are less tightly bound, so nuclear reactions that break nuclei apart produce energy. That's how fission works: very heavy elements like uranium and plutonium are split in a controlled way in nuclear power plants, or in an explosive way in atomic bombs. It still takes some effort to get the process started, like that initial push of the slinky, but the energy release can be immense.

Whether or not fusion energy will someday power our cities is yet to be seen. But in the meantime, we can always appreciate the giant fusion reactor in the sky, and the fact that it is a safe distance away and has billions of years' worth of hydrogen left to burn.

"In the meantime, we can always appreciate the giant fusion reactor in the sky"

ILLUSTRATION: MATTHEW HOLLAND

COMMENT

HERE'S WHAT HAPPENS IN YOUR BRAIN WHEN YOU'RE FACED WITH UNCERTAINTY

A complex series of chemical processes are triggered in our grey matter when outcomes are not obvious

When you hear the word 'uncertainty' what do you feel? Scared, anxious, excited or challenged? As humans we have a dichotomy of needs; part of us needs to feel safe, secure and to have some routine, and another part of us needs variety and opportunity. Life presents us with both uncertainty and change, and over the last three years this has been true to an even greater degree. With many global challenges still ongoing, we are likely to face even more of the unknown, so we had better get used to managing it.

So how do we detect uncertainty and which part of the brain is responsible for it? Researchers have found that noradrenaline is the key chemical involved in our response to uncertainty. Noradrenaline is a neuromodulator, which means it works within the brain to affect inhibitory or excitatory signals that the brain cells receive.

To investigate the role noradrenaline plays when we are faced with uncertain events, scientists at MIT conducted an intriguing experiment with mice. The animals were trained to pushed a lever down when they heard a high frequency noise. If they did this, they were rewarded with a drink of water. They also learned that they'd receive an unpleasant puff of air if the lever was activated when a low frequency noise was played. Simple enough. But the researchers added in an element of uncertainty, by including a sound where the frequency was unclear.

From this experiment, the researchers discovered that a small part of the brainstem called the locus coeruleus – an area that modulates noradrenaline – was essential in detecting uncertainty. When the high frequency was clear and the reward was expected for the mice, their noradrenaline release was small. But when the outcome wasn't clear, and the reward was a surprise, the release was much larger. For example, when a mouse received a puff of air instead of the reward it

ILLUSTRATION: DANIEL CRESPO

"Cognitive and emotional responses to uncertainty are a natural process"

was expecting, the locus coeruleus sent out a large burst of noradrenaline. Over time, the mice were less likely to take action and push the lever down when the reward was uncertain. According to the researchers, the mice were constantly adjusting their behaviour depending on what they'd experienced.

The study's conclusion: their brains learned to deal with different levels of uncertainty – and that the locus coeruleus is perhaps key to this process.

A study with humans carried out at University College London added two other neuromodulators, acetylcholine and dopamine, to the list of chemicals known to regulate our reaction to uncertainty. After running an experiment that asked participants to predict sequences of symbols, they discovered that acetylcholine helps us adapt to how our environment is changing and dopamine triggers us to action.

With any decision in the midst of uncertainty, there is a balance of risk and loss. While these chemicals underlie the mechanism of how we detect, adapt and act, there is also a process going on in one particular area of the brain, the inner prefrontal cortex, that has a huge impact on our ability to make decisions.

Scientists from Tel Aviv University have found that this area dictates our avoidance behaviour when under stress. They discovered that subjects' neurons in the prefrontal cortex were proven to respond much more to loss (negative outcome) than to gain (reward outcome) when they had them play a computer game that involved risk and opportunity. If someone lost the game, it provoked a response in their hippocampus – a brain area involved in memory process and feelings of anxiety – and they became more risk averse. This is helpful in understanding our reluctance in life to expose ourselves to uncertainty and how sometimes we shy away from making big decisions.

The way our brains deal with uncertainty plays a key role in how we approach life. Once we understand that our cognitive and emotional responses to uncertainty are a natural process, perhaps those big decisions can seem less intimidating – and we can make better choices.

BBC RADIO 1

Listen to Dr Radha Modgil on *Life Hacks* on BBC Radio 1.

DR RADHA MODGIL

(@DrRadhaModgil)

Radha is an NHS doctor, broadcaster and wellbeing campaigner. She is the medical expert on BBC Radio 1's Life Hacks. *Her first book,* Know Your Own Power *(£14.99, Yellow Kite), is out now.*

COMMENT

NO, IT'S NOT THE ARTIFICIAL INTELLIGENCE'S FAULT THAT IT'S SEXIST

AI designers should take more responsibility for the content their creations produce

Back in December, the internet was abuzz with a new app. For £1.79, Lensa AI would generate 50 artistic portraits based on uploaded headshots. It quickly topped the download charts. But when some people complained of sexualised and disturbing body modifications, the app creators put up a note that they couldn't guarantee non-offensive content. But when AI makes blunders, this type of disclaimer isn't enough.

When I tried Lensa AI's 'magic avatar' feature for myself, I selected my gender and uploaded 10 to 20 headshots. It quickly returned flowered fairies, fantasy warriors and other creative figures, all with recognisable features. Magical, indeed, except two of my images were nude, and, oddly, sporting giant breasts. Other female-identifying users also reported being portrayed naked, despite uploading only professional headshots.

Aside from undressing women, the app also appears to 'beautify' their faces and slim down their bodies. Other users reported that their dark skin was lightened, and an Asian journalist discovered that her images were overly sexualised compared to her white colleagues'. From a technical perspective, it's sadly not surprising that these AI portraits incorporate harmful stereotypes, including fetishising Asian women.

> "Is the app a reflection of society, or is it a reflection of historical bias and injustice?"

DR KATE DARLING
(@grok_)
Kate is a research scientist at the MIT Media Lab, studying human-robot interaction. Her book is The New Breed *(£20, Penguin).*

The reason is 'garbage in, garbage out', which is a saying that applies to most of today's AI systems. The output isn't magical, it depends mainly on what we feed into them. Lensa AI uses Stable Diffusion, a model that was trained on 5.85 billion pictures scraped from the internet. If you indiscriminately grab material from the web, you invariably wind up with an app that likes to draw big boobs on my small, perfectly fine chest.

Generative AI models need such massive amounts of training data that it's difficult to curate. And while it's possible to add certain safeguards, it's impossible to anticipate everything the AI will create. In order to release these tools at all, it makes sense that companies want people to use them at their own risk. For example, Open AI's ChatGPT website warns users that their chat tool may generate incorrect information, harmful instructions, or biased content.

But these companies are also benefitting from our willingness to view the AI systems as the culprits. Because autonomous systems can make their own content and decisions, people project a lot of agency onto them. The smarter a system seems, the more we're willing to view it as an actor on its own. As a result, companies can slap a disclaimer on the front, and a lot of users will accept that it is the AI's fault when a tool creates offensive or harmful output.

The issue goes well beyond 'magical' body edits. Chatbots, for example, have improved since Microsoft's infamous 'Tay' began spewing racist responses within a few hours of its launch, but they still surprise users with toxic language and dangerous prompts. We know that image generators and hiring algorithms suffer from gender biases, and that the AI used in facial recognition and the criminal justice system is racist. In short, algorithms can cause real harm to people.

Imagine if a zoo let a tiger loose in the city and then said "we did our best to train it, but we can't guarantee the tiger won't do anything offensive". We wouldn't let them off the hook. And even more so than the tiger, an AI system doesn't make autonomous decisions in a vacuum. Humans decide how and for what purpose to design it, select its training data and parameters, and choose when to let it loose on an unsuspecting population.

Companies may not be able to anticipate every outcome. But their claims that the output is simply a reflection of reality is a deflection. Lensa AI's creators say that "the man-made unfiltered data sourced online introduced the model to the existing biases of humankind. Essentially, AI is holding a mirror to our society". But is the app a reflection of society, or is it a reflection of historical bias and injustice that a company is choosing to entrench and amplify?

The persistent claim that AI is neutral is not only incorrect, it obscures the fact that the above choice is not neutral, either. If you can't stop your app from perpetuating existing societal problems with female body image, revenge porn and racism, and you choose to release it anyway, maybe you're morally responsible for the harm it generates.

It's nifty to get new profile pics, and there are many more valuable and important applications for generative AI, but we don't need to shield companies from moral or legal responsibility in order to get there. In fact, it would be easier for society to lean into AI's potential if creators were accountable. So, let's stop pointing our fingers at AI and talk about who really generates the outcomes of our technological future.

ILLUSTRATION: VALENTIN TKACH

REALITY CHECK

SCIENCE BEHIND THE HEADLINES

'Kraken' COVID variant | Mid-life crises | Face masks

REVIEW

KRAKEN COVID VARIANT: ALL YOU NEED TO KNOW ABOUT THE UK'S XBB.1.5 CORONAVIRUS STRAIN

A significant new subvariant of the coronavirus, nicknamed 'Kraken', could soon cause a major upsurge in UK case numbers. Should we be worried?

"All the signs are that this is going to cause a bigger wave than we saw in the summer of 2022"

BBC

Visit the BBC's Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

WHAT IS THE 'KRAKEN' XBB.1.5 SUBVARIANT?

It's the highly transmissible XBB.1.5 subvariant – another offshoot of the Omicron SARS-CoV-2 virus variant – that's been detected in 38 countries to date, including the United Kingdom.

Although the United States is currently the hotspot for the subvariant (XBB.1.5 accounting for an estimated half of the country's coronavirus cases), the European Centre for Disease Prevention and Control (ECDC) predicts it will become the dominant form of coronavirus in Europe between February and March this year.

So far, just less than a tenth of the world's XBB.1.5 cases have been identified in the UK. But many scientists, including Prof Paul Hunter from the Norwich Medical School of the University of East Anglia, say a large wave of COVID cases is imminent.

"All the signs are that this is going to cause a bigger wave than we saw in the summer of 2022," he says. "Infections are falling in the UK at the moment, [but] I expect that to reverse over the next few weeks.

The new subvariant is a mix of other Omicron subvariants. As signified by the X in its name, XBB.1.5 (and its ancestor XBB) came about through a recombination of subvariants BA.2.10.1 and BA.2.75. But it's not just the mix of these subvariants that makes XBB.1.5 such a problem – there are over 50 'X' subvariants that haven't caused major concern so far. The main issue with XBB.1.5 is that its spike proteins have mutated significantly.

"A lot of scientists are concerned that we're at a really high risk of another relatively severe wave. We just haven't seen this jump in transmissibility in quite a while," says Dr Jeremy Rossman, senior lecturer in virology at the University of Kent.

WILL OUR CURRENT VACCINES WORK AGAINST XBB.1.5?

At the moment, there's very little data to be exactly sure, but the World Health Organization says there are signs the variant could be one of the most "antibody-resistant variants to date".

One preliminary study indicated that XBB.1 variants were up to 21 times more evasive against vaccine antibodies, compared to the variant dominant in the UK since June 2022 (BA.5).

Another study that hasn't been peer-reviewed suggests that people who have been previously infected with the virus and have received three or four doses of an mRNA COVID vaccine (such as Moderna or Pfizer) are still unlikely to have the immunity needed to prevent an XBB.1.5 infection.

"Even for people who have had the original vaccine and boosters, the protection from getting infected and having symptoms with XBB.1.5 is very poor," says Rossman.

"The protection given by bivalent boosters [the second generation of vaccines, rolled out during autumn 2022 in the UK] is a little better. But it's still dramatically reduced – some estimating the efficacy is only 30 per cent or less."

Although the protection a jab provides against infection (as well as developing symptoms and long COVID) is reduced against XBB.1.5, vaccines "still remain effective against severe disease," according to the ECDC. It's also possible a new generation of boosters could be produced, just like last year's bivalent boosters. That said, there are no current plans for their production.

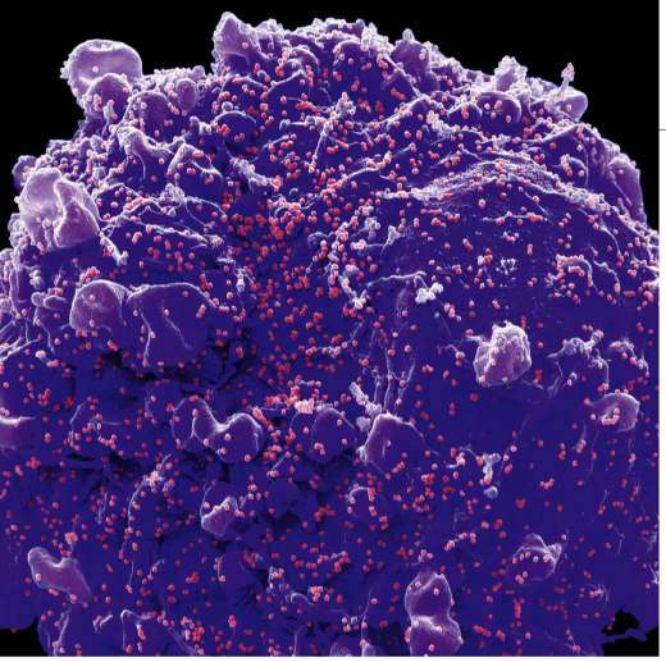
WILL A LATERAL FLOW TEST STILL DETECT XBB.1.5?

As with previous Omicron variants, our current lateral flow tests are still likely to detect the virus. →

SHUTTERSTOCK, GETTY IMAGES

OPPOSITE
The current COVID vaccines may not prevent infection with the XBB.1.5 variant, but should stop the symptoms from being severe

BELOW
Testing remains vital for tracking the progression of new and existing variants



ABOVE The Omicron variant (seen here in red on a kidney cell) is currently the dominant form of COVID in the UK

→Although, highly transmissible variants like XBB.1.5 may work so quickly in the body that you could take a lateral flow test after the point where the virus is detectable.

"It's not necessarily that the test can't pick up the virus," Rossman explains, "but that if the virus replicates really fast, like XBB.1.5 might, sometimes that means the infection process happens so quickly inside you that you only have that peak of virus that's high enough to detect for maybe six hours."

He adds that this doesn't mean everyone will only be able to test positive for six hours, only some people. Others could test positive for a week or more.

Unfortunately, a shorter infection time doesn't necessarily mean you'll spend any less time ill. And while the infection time with highly transmissible variants is lower on average, this is only an average. It may take a week or longer before you exhibit symptoms and spread the virus, or it could take a day.

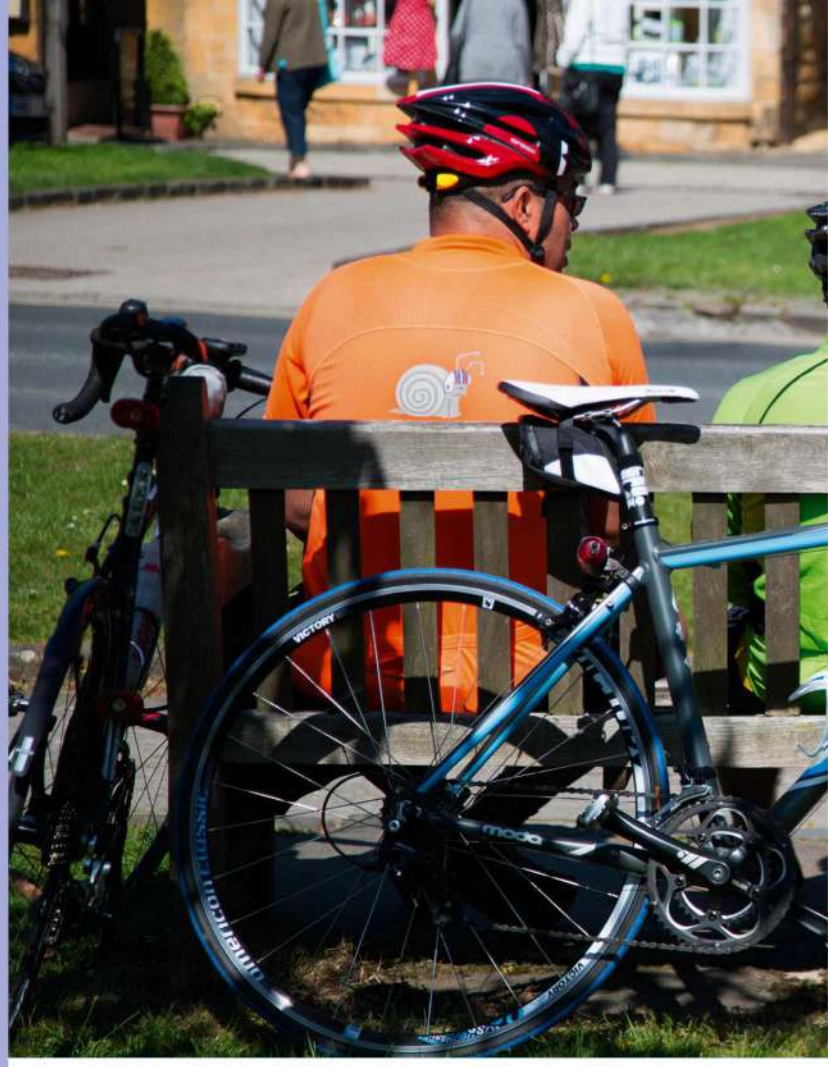
According to Rossman, this means lateral flow tests remain a vital tool. "They should still work and they're certainly worthwhile," he says.

SO HOW DANGEROUS IS XBB.1.5?

At the moment, scientists think that XBB.1.5 is no more likely to cause serious disease in someone than previous variants. But because XBB.1.5 is much more transmissible, there are fears it could spread to many more people. And with more people infected, there's more chance that a number of them could become seriously ill.

"Anything that makes the virus more transmissible can often lead to an increase in hospitalisations of vulnerable people. And even if there's no change in the severity of the virus, more people could get sick," says Rossman.

by **THOMAS LING**
Thomas is the digital editor of BBC Science Focus.



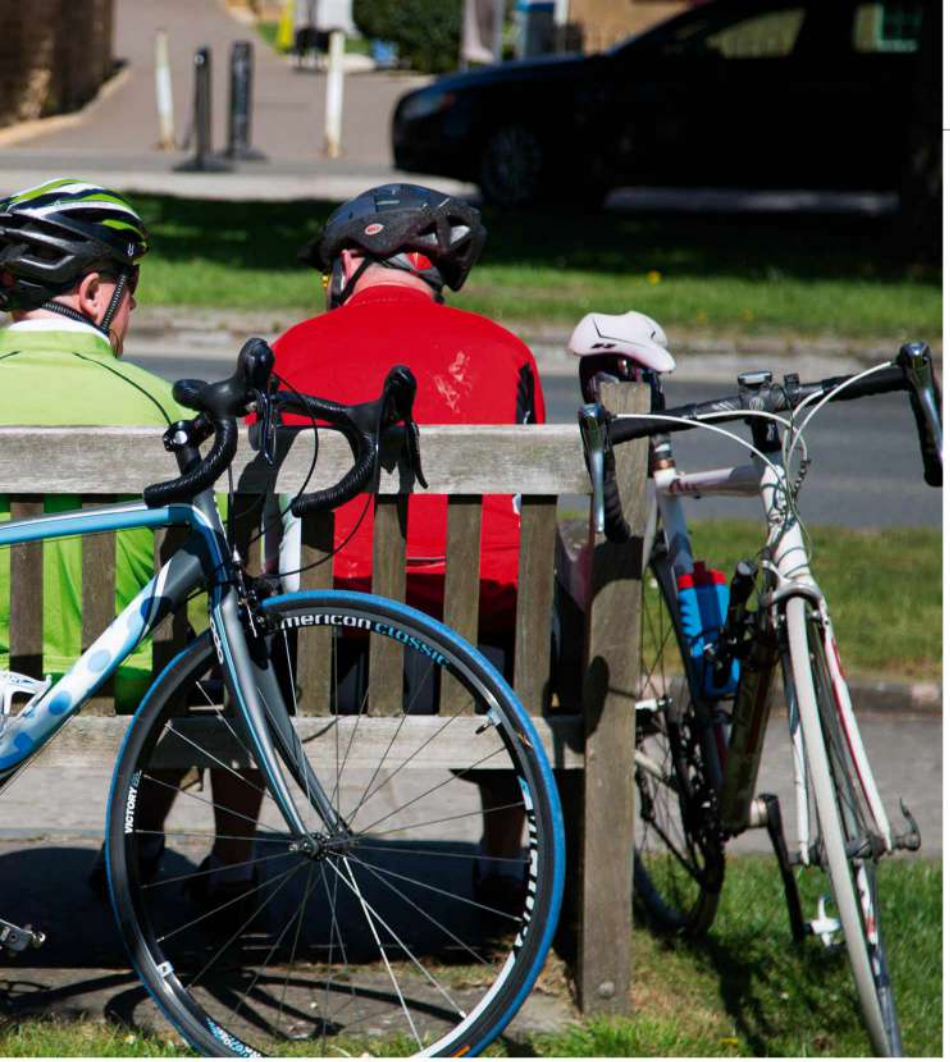
ANALYSIS

MID-LIFE CRISIS: A PSYCHOLOGIST EXPLAINS HOW TO EMBRACE IT

Far from being a period of existential angst and decline, our middle years can be a period of growth

There are many good reasons for feeling a little stress and melancholia when you reach life's halfway point. Before, you might have felt you were on an upward curve – growing physically and mentally stronger with age, learning and earning more. But now, the end is nearer than the start, and you might sense the beginning of a slow descent toward decline and ultimate decrepitude.

Layered upon that unsettling shift in perspective, there are some pressing practicalities for many people, such as the demands of children, more responsibility at work, and perhaps caring for ageing parents too. No wonder that many middle-aged people are said



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ABOVE
A sudden drive to get out in the fresh air for some fun with mates and a little friendly competition... Can we be sure these are signs of a crisis?

"The fact is, the very notion of a mid-life crisis is more of a cultural invention than it is a psychological reality"

to experience a 'mid-life crisis' – a term coined by the Canadian psychoanalyst Elliott Jaques, first at a scholarly conference presentation in London 1957, then later, in print, in his 1965 paper *Death And The Mid-Life Crisis*.

Jaques's term caught on, thanks in part to the mega-selling *Passages: Predictable Crises Of Adult Life* by US journalist Gail Sheehy, published in 1976, which featured her interviews with people in their late-30s and early-40s, many of whom described being in turmoil.

To this day, jokes abound of what people will do to alleviate their age-acquired angst: 40-something men buying sports cars, or middle-aged women leaving their marriage to go backpacking around the world. According to a study carried out in 2004, between 10 and 20 per cent of people report experiencing a mid-life crisis. Yet, the fact is, the very notion of a mid-life crisis is more of a cultural invention than a psychological reality.

Each stage of life comes with its own challenges and, anecdotes aside, there's little objective evidence for mid-life being a time of particular crisis. Consider a study from 2010 led by the University of Notre Dame, Indiana, that drew on two long-running surveys of people's life satisfaction, one conducted in Germany involving about 40,000 people, the other conducted in Britain since 1991 and involving over 20,000 people.

Both surveys showed that life satisfaction remains pretty constant through life, until old age. In fact, the British survey showed some evidence for modest declines in life satisfaction in early adulthood, but with a positive rebound from mid-life onwards, until much later in life.

There are other reasons to feel positive about reaching the mid-life point. Whereas younger adults are having to find their way and prove their worth at work, the chances are that if you're middle-aged, your own professional situation is more settled. Research shows that by mid-life, people are able to find more intrinsic motivations for their work – the pleasure and meaning of it – rather than extrinsic, which is more about pay and promotion.

And while so-called 'fluid intelligence' (mental ability) can start to decline as early as our 20s, 'crystallised intelligence' – your vocabulary and general knowledge – continues to grow through life and is likely higher than it's ever been. Comprehension and arithmetic also tend to be at their peak in mid-life or even later. Perhaps unsurprisingly, there's also some evidence that wisdom continues to increase into mid-life and beyond.

Another reason for viewing mid-life with optimism comes from the research on the personality changes that typically take place over a person's life. Thanks to a spate of long-term studies that have assessed the →

ABOVE Are you 'over the hill' when you hit middle age? The research suggests you're actually wiser, happier and more driven

→ same groups of people over many decades, we know that most of us can expect to grow more emotionally stable with age, more conscientious and friendly, at least into mid-life and sometimes later.

Even when it comes to physical challenges and mid-life, there's a positive story to tell. You've probably noticed the abundance of men of a certain age donning Lycra and heading off for a day of fun on their bikes, leading to the pejorative MAMIL acronym – 'middle-aged men in Lycra' (of course plenty of women enjoy cycling and other sports too).

In defiance of those who mock, these people are having fun and, for those who wish to, they can hold their own in competition. In fact, there has been a noticeable increase in people over 40 competing in endurance sports (in the research literature, they're known more respectfully as 'master athletes'). For instance, male 'master runners' have made up more than half the men completing recent New York City marathons.

There are likely multiple reasons for this demographic shift in sports, some of it no doubt due to improvements in health care and awareness, leading to better, lasting functional fitness through life. On the psychological side, some intriguing research from the University of Oregon found that people's competitiveness increased with age before peaking at around age 50.

So, looking at the entire picture, far from middle-aged people being over the hill and in a state of crisis, they're often wiser, happier and more driven than they've ever been. As with many things in life, much of it comes down to perspective and by focusing on the positives, you might find there's some truth to another popular trope: that life really does begin at 40.

by **DR CHRISTIAN JARRETT**

Christian is a cognitive neuroscientist, science writer and author of Great Myths Of The Brain *and* Be Who You Want: Unlocking The Science Of Personality Change.

COMMENT

FACE MASKS: ARE THEY LESS EFFECTIVE THAN THEY WERE?

As various illnesses circulate, calls for face coverings are once again being heard. Are they still a good way to reduce risk of COVID?

With fresh concerns over rising flu, Strep A and COVID XBB.1.5 cases, health officials across the UK are scratching their heads over one key question: should we all be wearing masks again?

While the UK Health Security Agency has advised adults who are displaying flu or COVID symptoms to wear a face covering, some public figures, such as Scottish First Minister Nicola Sturgeon, have advised all healthy adults to wear a mask in certain settings.

But as COVID begins to stabilise in the UK, some scientists have questioned how effective face masks are at controlling current case numbers.

"Masks were really helpful early in the pandemic," says Prof Paul Hunter from the Norwich Medical School of the University of East Anglia. "But there is evidence that masks were an essential part of our control measures up until the point that we'd effectively vaccinated as many people as we were going to. What we've seen this year is that their protection has evaporated."

This claim hinges on data collected by the Office of National Statistics (ONS) between November 2021 and May 2022 that monitored how likely people who did and didn't wear a mask were to test positive for COVID. The figures indicate that towards the end of 2021, children and adults who said they 'always' wore a mask at work or school were less likely to test positive for COVID-19 than those who 'never' or 'sometimes' wore a mask.

From January to May 2022, however, the likelihood for both groups to test positive was extremely similar.

But some scientists have said there isn't enough data to draw a solid conclusion, highlighting how the ONS figures were last collected in May 2022 – eight months ago. "You can draw a general conclusion from these data. But I think an informed conclusion would be unwise because of the complexity of the situation. The virus has changed substantially over

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"There's no real need to wear a mask in an open high street, but in enclosed, high-risk settings, it's simply sensible"

ABOVE
Are we safe to leave masks behind now that vaccinations have reached high levels?

that period," says Hugh Pennington, emeritus professor of bacteriology at the University of Aberdeen's School of Medicine, Medical Sciences and Nutrition.

According to Hunter, while mask-wearing and school closures had a big impact at the start of the pandemic, their effect has lessened as we approach 'endemic equilibrium' (where case numbers remain at a relatively low and constant level, with most people having had COVID at least once and having received at least one vaccination). "As more people get the infection and recover, the risk changes. Many of the people you may infect are actually immune, so they don't actually get infected," Hunter says.

There's been another big change since the pandemic started: the SARS-CoV-2 virus itself. "Omicron is so infectious that it'll spread no matter what we do," says Hunter.

Some research has also demonstrated that masks may only delay infections, a conclusion reached in a US study that compared schools with and without mask mandates across 1,832 counties. Initially, schools with mask mandates were less likely to seek care for COVID, but the difference in numbers between the two groups disappeared in a few weeks.

Hunter says: "I think – and this is a theory – that children who have never worn masks in schools are more likely to have had an infection earlier on. So by now, they're more likely to be a lot more immune than children who have always worn masks. At this point, the extra immunity balances out reduced exposure.

"And if you've been religiously wearing a mask, you're less likely to have had COVID. You're less likely to have what's called hybrid immunity – immunity from a previous infection and vaccine. That's the best immunity you can have."

While he views infection as largely inevitable, Hunter does recommend that some groups should still wear a mask in public. "If I was much older or had a health condition that put me at risk, I would continue to wear a mask," he says.

Other scientists argue that all adults should wear masks in certain settings to protect themselves and others. "I think the public health advice has to be in favour of masks," says Prof Christopher Dye, epidemiologist and public health expert at the University of Oxford. "You really don't want to get infected, so you can protect yourself from future infections. Even now, it's not a good idea to get COVID. There's no real need to wear a mask in an open high street, but in enclosed, high-risk settings, it's simply sensible." SF

by THOMAS LING
Thomas is the digital editor of BBC Science Focus.

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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

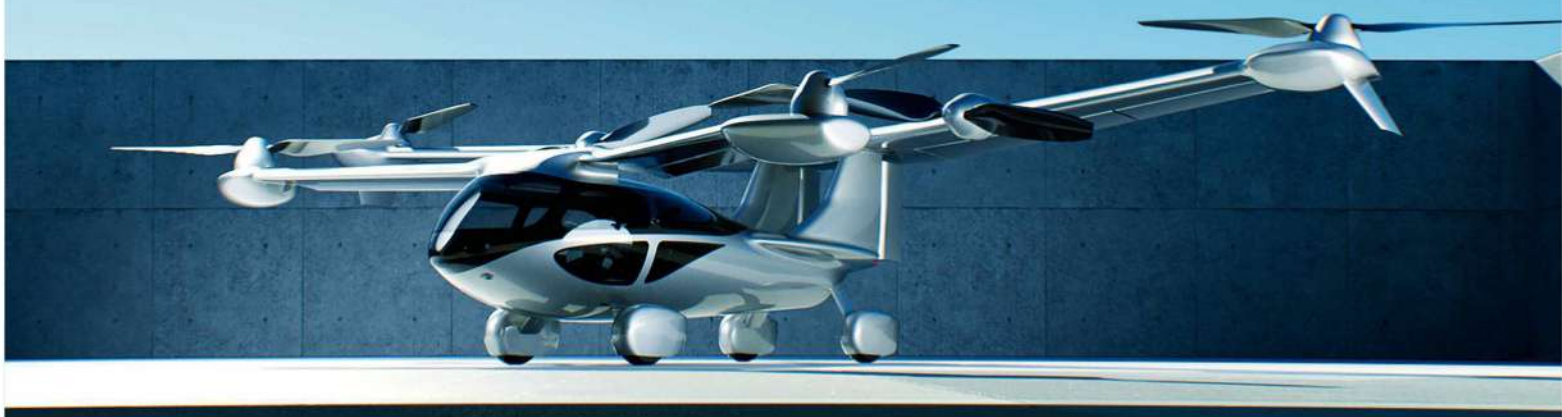
CES SPECIAL

A flying car at last? p44

LAST MONTH, JOURNALISTS DESCENDED UPON THE WORLD'S BIGGEST TECH EVENT, CES, TO GET A SNEAK PEEK AT THE INNOVATIONS THAT WILL MAKE WAVES IN 2023

INNOVATIVE TECH

OUR ROUNDUP OF SOME OF THE MOST CREATIVE IDEAS



...a Jetsons-style future

If the show *The Jetsons* was to be believed, we should all own flying cars by the 2060s. CES 2023 gave a glimpse of that future, with the brand Aska showing off its four-seater flying car. The Aska A5 has a 250-mile (402km) flight range and could, in theory, be driven on the road as well as flown. While just a concept for now, Aska is already working on getting it road-certified and has hopes to be in operation in the near future.

Aska A5
aska.com

...a car powered by solar

With cities and entire countries closing their doors to new petrol and diesel cars, all eyes are on electric cars. But while most seem to be following a similar formula, the new kid on the block, Lightyear, is trying something different. It's still electric, but across the roof of the car is a layer of solar cells that help give the car an additional 70km (43 miles) of range per day from sunlight alone. This means for short journeys, you might not need to charge via a socket at all. Lightyear also says it has the lowest energy footprint on the market, but these are easy claims to make when the car isn't set to go on sale until 2025.

Lightyear 2
lightyear.one

...tracking your alertness through your wrist

With smartwatches, you're able to track everything from the steps you take to your ovulation. And if that wasn't enough, Citizen is now looking to track your alertness and fatigue throughout the day. It does this by harnessing research from the NASA Ames Research Center, along with AI tools from IBM. The watch will learn your sleeping patterns and uses a mini test to assess your daily alertness.

Citizen CZ smartwatch
citizenwatch.co.uk

...laptops going 3D

Three-dimensional viewing has come a long way from clumsy movie jump scares and flimsy plastic glasses. At this year's CES, Asus demonstrated its latest laptop, complete with 3D effects... without any glasses or headsets. Instead, the new Asus ProArt Studiobook utilises a lenticular lens and advanced eye tracking to create a 3D image for the laptop user. The laptop renders separate images for each eye, following the position of your head to adjust them accordingly. It can even be used by two people at once.

Asus ProArt Studiobook 16 3D OLED
asus.com

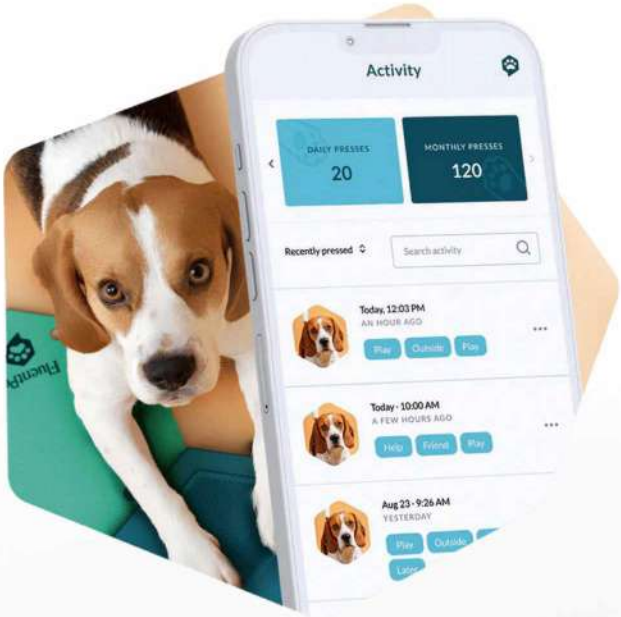
...screens on top of screens

The days of normal laptops are long gone, now we are seeing companies investigate some weird and wonderful alternatives. At CES 2023, Lenovo unveiled its new Yoga Book 9i. It is, in essence, two tablets stuck together. You can use it as one super-long tablet, or as a laptop with a second screen acting as a keyboard, or two separate screens. It even comes with an attachable keyboard, if you want to keep it more like a traditional setup. Lenovo is looking to give users a single device that can replace laptops and tablets for one unique experience.

Lenovo Yoga Book 9i
lenovo.com

WEIRDEST GADGETS

THESE DEVICES ARE JUST SO BONKERS, WE COULDN'T RESIST!



...a way to chat to your pets

It can sometimes be hard to understand the inner intricacies of what your pets are trying to communicate – if only they could speak our language. While we are still a long way from a pet translation device, the company FluentPet has been working on a product that allows your pet to press buttons that play recordings of a word, communicating their inner thoughts. The idea is that your dog or cat will already know what words like 'walk' or 'food' mean, and this is simply a way for them alert you to what they want. At CES, the company announced FluentPet Connect, which allows your pet to send messages to your phone, via the associated app.

FluentPet Connect
fluent.pet

...a robot cushion to cuddle

Do you ever wish that your pillow could breathe? We're going to go ahead and assume not, and yet that is exactly what the Fufuly pillow does. This Japanese robotic cushion becomes bigger and smaller, just like your lungs inflating and deflating as you breathe in and out. By holding the cushion, your breathing will, in theory, synchronise with the pillow. Fufuly claims that matching your breathing to the pillow's rhythm will calm you down and help boost productivity. In a world of backflipping robots and conversational AI, it is nice to see a robot that we're not worried about taking over the world.

Fufuly
fufuly.jp

...eyebrows you can print

In recent years, the beauty industry has upped its game regarding high-tech products, but this new eyebrow printer really took us by surprise. L'Oreal's Brow Magic uses augmented reality and 2,400 tiny nozzles to print up to 1,200 dots per inch. Scan your face using the app and the device can recommend various eyebrow shapes, effects and styles, and then prints your new eyebrows onto your face. It works with different hair colours, textures and skin tones, and if you don't like the results you can easily get rid of them with makeup remover.

L'Oreal Brow Magic
loreal.com

...the sensor that wants to be peed on

The relationship with your toilet can often feel a little one-sided; you give, but it doesn't give back... until now. The U-Scan, made by health company Withings, is a sensor that you attach to the toilet bowl. It uses two separate sensors to analyse your urine every time you go for a pee. One sensor measures metabolic information like your dehydration and vitamin C levels, while the other is for those looking to track their menstrual cycle to see when fertility is highest. It's unique, and in Withings's own words: "Welcome to a new era for urinalysis".

Withings U-Scan
withings.com

ACCESSIBILITY TECH

INNOVATIVE APPLIANCES TO MAKE LIFE EASIER FOR EVERYONE

...a modular beauty assistant

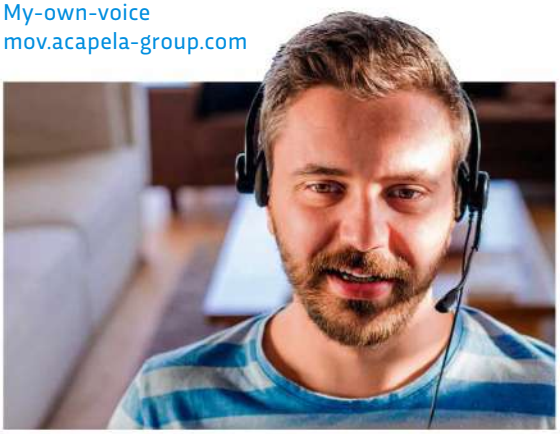
An eyebrow printer wasn't the only device L'Oreal unveiled at CES. The beauty company has also announced HAPTA, to help those with limited hand and arm mobility to apply makeup. The device is a grip with a magnetic attachment, which is being piloted with Lancôme lipstick, but eyeliner or other makeup tools should be available in future. The HAPTA offers 360° of rotation and stays in position during use, with the ability to lock in customised settings. As L'Oreal states, an estimated 50 million people live with limited fine motor skills, and the HAPTA aims to give them more control.

L'Oreal HAPTA
loreal.com

...create a digital copy of your voice

Machine learning has been utilised in everything from chess-dominating robots to witty chatbots, but in the background, the technology is being used to improve people's lives. My-own-voice is a company using machine learning to create synthetic versions of people's voices. If someone is soon going to lose the ability to speak, the service can take just 10 minutes of voice recordings and create a replica of their speech. Then, through a text box, the user can type a sentence and have it read back in a replicated version of their own voice.

My-own-voice
mov.acapela-group.com



...removing barriers for gaming

Sony has been making strides in the world of accessible gaming over the years and CES 2023 was possibly its biggest commitment to date. Project Leonardo is a new controller for the PlayStation 5. It is made for players with limited motor control who can't hold a controller for long periods, or who struggle with the small buttons. Leonardo is a circular device with a joystick and larger versions of each button. It comes with a host of swappable parts and is customisable to an individual's preferences.

Sony Project Leonardo
sony.com

...superhuman strength in the workplace

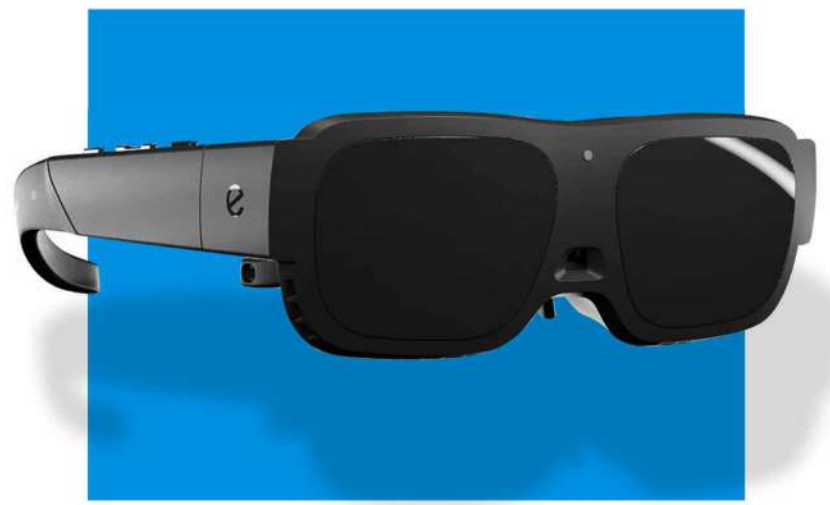
Science-fiction movies would have you believe that exoskeletons will turn us all into crime-fighting warriors, capable of leaping great distances and flipping cars. In reality, the technology could actually help to revolutionise manual labour. At CES, German Bionics released a new version of its exoskeleton, the Apogee, a lightweight suit that makes it easier to lift heavy objects. The suit offers real-time data readouts and monitors ergonomic performance to make sure the user is lifting safely.

Apogee exoskeleton
germanbionic.com

...smart glasses for the visually impaired

Most previous iterations of smart glasses have been about taking photos and reading notifications, but eSight Go is instead using smart technology to improve accessibility. These glasses are designed for people with significant central vision loss. A small high-speed camera captures everything the individual is looking at, then a set of algorithms optimises and enhances the footage, presenting it onto two OLED monitors, one in front of each eye. The brain is then able to process these images, helping the user to see with much higher clarity – up to 20/20 vision, eSight claims. The device is hands-free and wireless, so can be used anywhere.

eSight Go
esighteyewear.com



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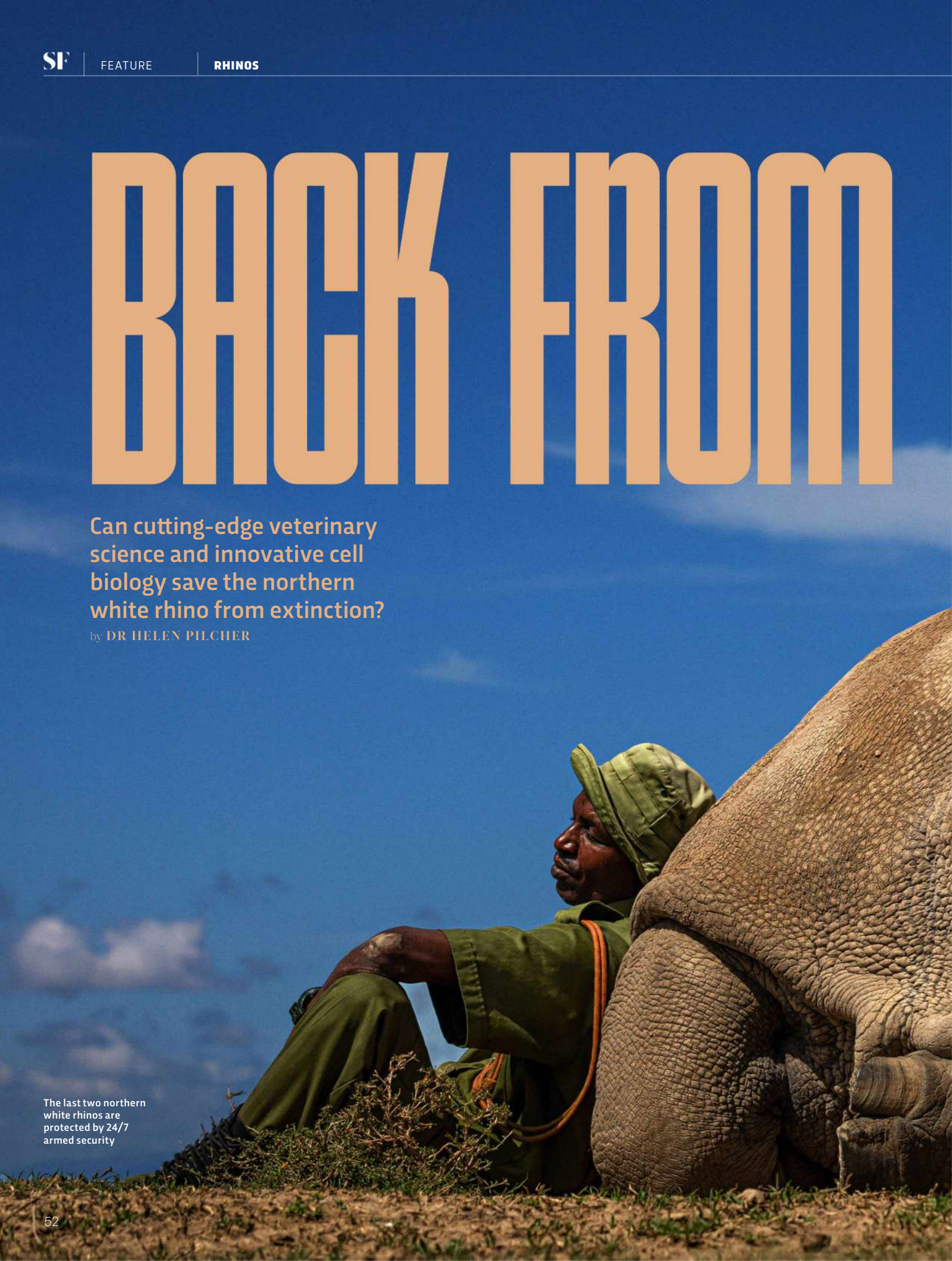
BACK FROM

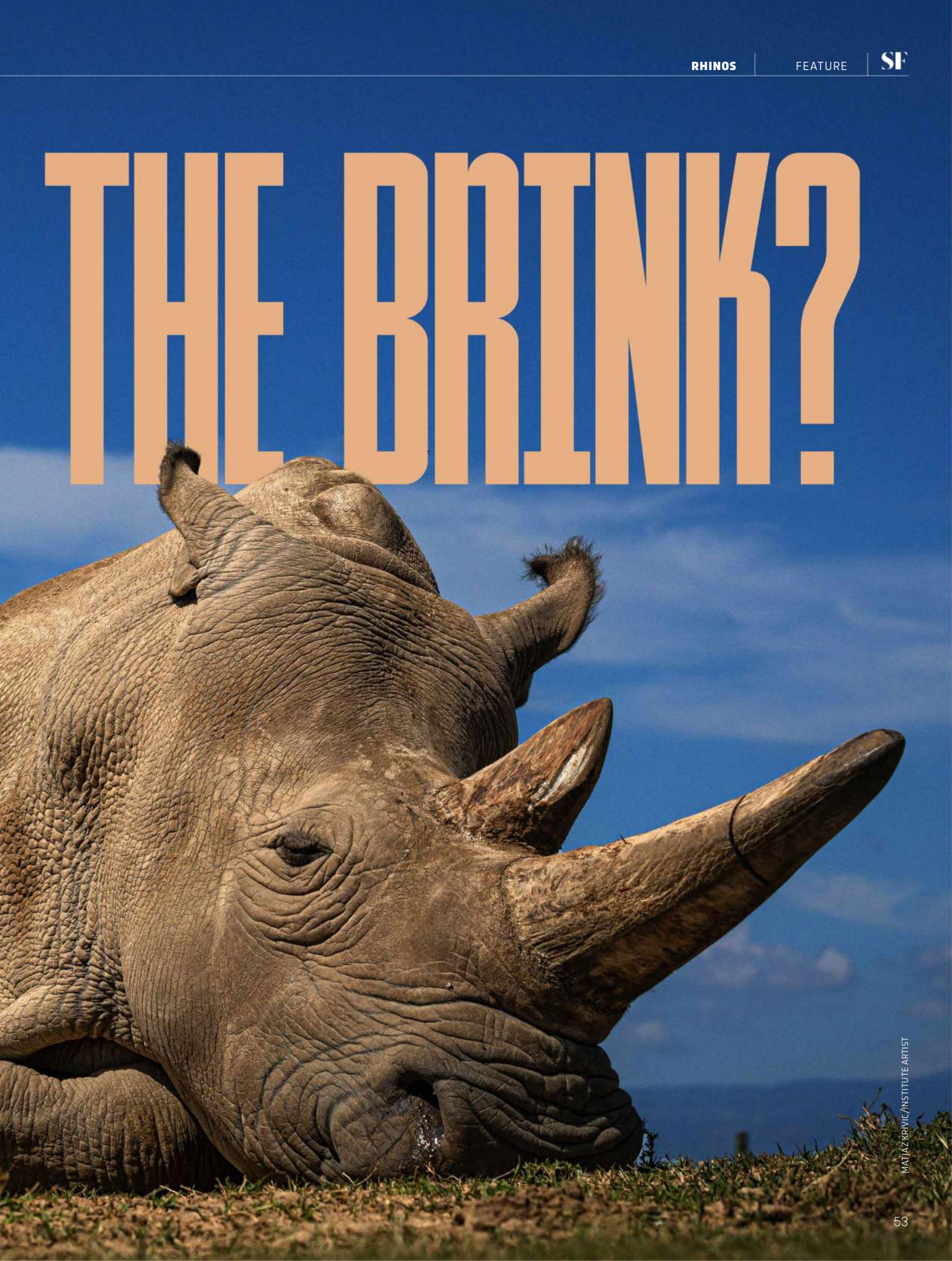
Can cutting-edge veterinary science and innovative cell biology save the northern white rhino from extinction?

by DR HELEN PILCHER



The last two northern white rhinos are protected by 24/7 armed security

THE BRINK?



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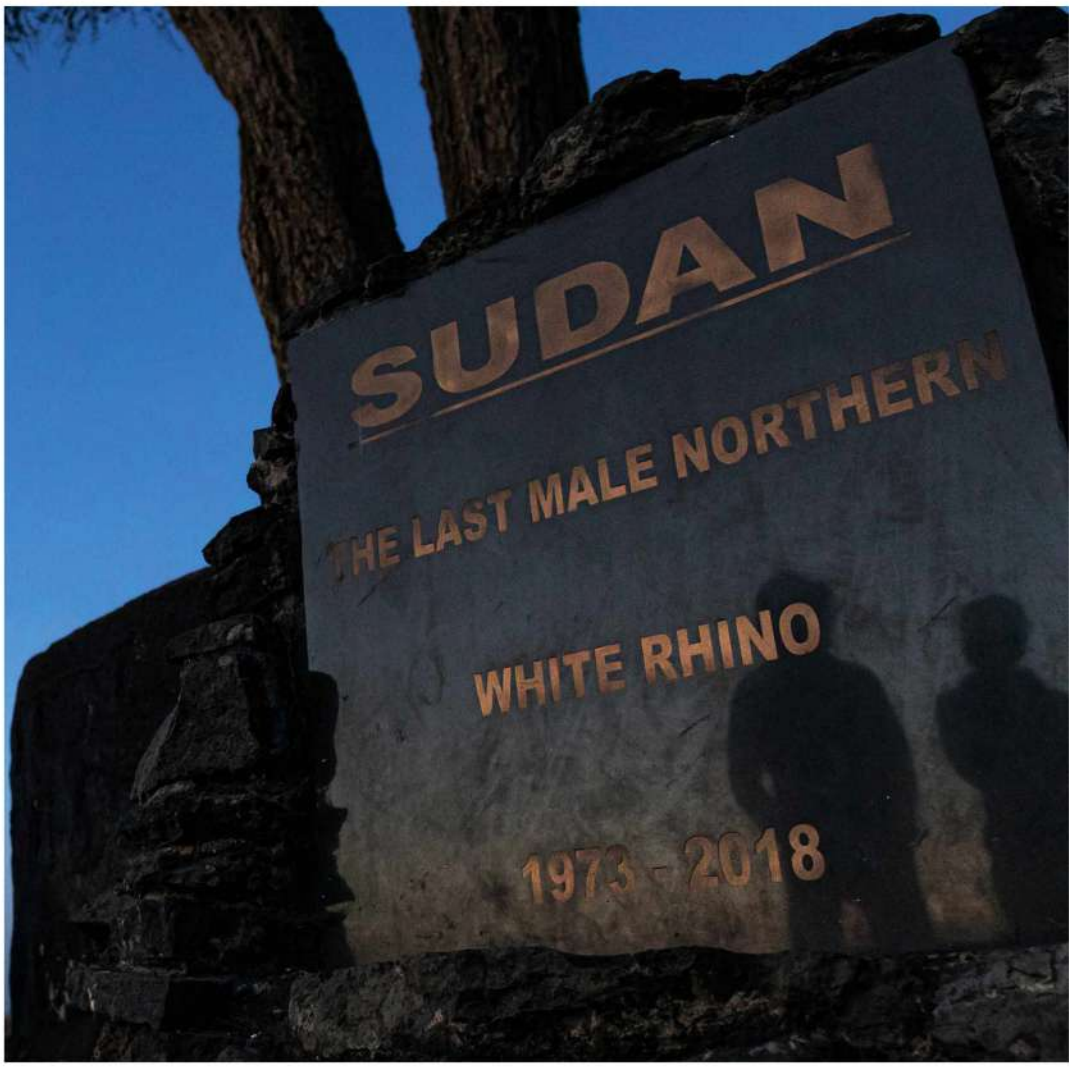


It's early morning in Kenya's Ol Pejeta Conservancy, and under a wide African sky, the last two northern white rhinos left on Earth go for a stroll. From time to time, they pause; tasselled ears twitching, as they lower their broad, flat muzzles to nibble the parched grass. Later in the day, as the mercury rises, they will retire to shady spot and have a siesta, watched over by the armed guards who protect them from poachers around the clock. The rhinos' names are Najin and Fatu, and they are mother and daughter. Neither can reproduce naturally, and even if they could, there are no males left for them to mate with. This makes the northern white rhino as good as gone, or, as scientists would call it, 'functionally extinct.' Najin and Fatu are 'dead rhinos walking.'

In decades gone by, this would have been the end of the line for the northern white rhino, but not anymore. For the last seven years, an international group of scientists have been working to bring this charismatic giant back from the brink. The BioRescue project involves cutting-edge veterinary science, cell biology and the creation of 'test tube rhinos'. If all goes according to plan, the pitter patter of not-so-tiny rhino feet could be just a few years away.

"We have hope," says veterinarian Prof Thomas Hildebrandt from the Leibniz Institute for Zoo and Wildlife Research, who is the project leader.

But the biggest challenge may not be in producing new rhinos, but the calming of critics who believe that the work should never go ahead in the first place.

STEEP DECLINE

At the start of the 20th Century, northern white rhinos were a common site on the savannahs of eastern and central Africa, but then poaching, habitat destruction and armed conflict caused populations to crash. By the 1980s, there were just 15 animals left in the wild. When they died, conservationists hoped that the small

ABOVE Najin (left) and her daughter Fatu are the last two northern white rhinos

LEFT Grave of Sudan, the last northern white rhino male, in the middle of Ol Pejeta Conservancy plains

number of animals left in captivity would be able to kickstart the population, but the rhinos didn't get the memo. Northern white rhinos don't breed well in captivity, and the last male, known as Sudan, died in 2018.

Gone but not forgotten, Sudan is just one of a number of northern white rhinos who may still be able to produce offspring from beyond the grave. Before the final few males died, Hildebrandt and colleagues started to collect and freeze their semen. It's a delicate procedure, performed under general anaesthesia, that sees a cylindrical probe guided up the animal's rectum, before a few mild pulses of electricity are applied to stimulate the prostate gland. Hildebrandt has developed and refined the method, so it can be performed quickly, painlessly and successfully. Now the team have semen samples stored away from four of the last male northern white rhinos, including Sudan.

Some of the samples were used to artificially inseminate Najin and Fatu, but when the females failed to become pregnant, the team turned their attention to in vitro fertilisation (IVF). IVF involves the fusion of egg and sperm in a dish to create a 'test tube embryo', but rhino eggs are not easy to come by. Hildebrandt spent years devising a method to harvest them, working with females from other, more common, rhino species. But by the time it was perfected, the only female northern white rhinos remaining were Najin and Fatu. Najin, however, is unable to donate eggs because she is elderly and has an ovarian tumour, which leaves 22-year-old Fatu as the only available donor.

Now Fatu undergoes the procedure roughly once every three months. Hildebrandt manoeuvres an ultrasound-guided needle a metre or so up her rectal passage, punctures through to the ovary, and then aspirates the immature eggs, known as oocytes. "It's quite stressful because we only have two hours to work whilst Fatu is asleep," says Hildebrandt. Then, when the anaesthetic wears off, she's back on her feet within minutes, none the worse for wear. →

"THE NORTHERN WHITE RHINO IS AS GOOD AS GONE, OR, AS SCIENTISTS WOULD CALL IT, 'FUNCTIONALLY EXTINCT'"

RHINO ROUNDUP: THE FIVE SPECIES ALIVE TODAY

WHITE

NUMBER REMAINING: 16,000
STATUS: NEAR THREATENED
DISTRIBUTION: SOUTH AFRICA, NAMIBIA, BOTSWANA, ZIMBABWE, KENYA, ZAMBIA AND UGANDA

BLACK

NUMBER REMAINING: 6,000
STATUS: CRITICALLY ENDANGERED
DISTRIBUTION: KENYA, NAMIBIA, SOUTH AFRICA, TANZANIA AND ZIMBABWE

INDIAN

NUMBER REMAINING: 4,000
STATUS: VULNERABLE
DISTRIBUTION: INDIA AND NEPAL

JAVAN

NUMBER REMAINING: 70
STATUS: CRITICALLY ENDANGERED
DISTRIBUTION: JAVA

SUMATRAN

NUMBER REMAINING: 40
STATUS: CRITICALLY ENDANGERED
DISTRIBUTION: SUMATRA AND BORNEO

GETTY IMAGES X4, ALAMY X3, MATJAZ KRIVIC/INSTITUTE ARTIST

"THE GOAL IS TO REINTRODUCE VIABLE POPULATIONS OF NORTHERN WHITE RHINOS INTO THE WILD, TO ACT AS ECOSYSTEM ENGINEERS"

→Hildebrandt and his team have successfully performed the procedure 11 times since 2019, and have collected 164 oocytes, but these are large cells that do not freeze or store well, so they need to be used fresh. The oocytes are therefore flown to a specialist lab in Italy where they are matured in a bespoke cocktail of chemicals, and then used for IVF. Thawed sperm is injected directly into the egg, which then starts to divide to form an embryo.

This is the first part of the IVF procedure. Just like its human equivalent, it doesn't always work and yet, the scientists have still managed to create 24 embryos, using eggs from Fatu and sperm from two different males. While you can't freeze oocytes, you *can* freeze early embryos, so for now these 'test tube rhinos' are frozen away in a vat of liquid nitrogen, waiting for the time when Hildebrandt is ready for the next stage: implanting the embryo into the uterus of a surrogate rhino mother. But which rhino to use?

Neither Najin nor Fatu are suitable surrogates. Najin's back legs are too weak to carry a pregnancy, and although Fatu can produce oocytes, she has problems with her uterus. Fortunately, the northern white rhino has a close relative called the southern white rhino. Listed as 'near threatened' by the International Union for the Conservation of Nature, there are around 16,000 southern white rhinos living in eastern and southern Africa, including 39 who live at Ol Pejeta. Two of these have been earmarked by the conservancy as surrogates. Later this year, Hildebrandt and his team hope to fly to Kenya to implant one of their northern white embryos into one of these surrogates. Rhino pregnancies last around 18 months, so if things go well, the first calf could be born as soon as 2024. Then, as more surrogates are recruited, more calves could follow, but there's an elephant in the room.

FAMILY MATTERS

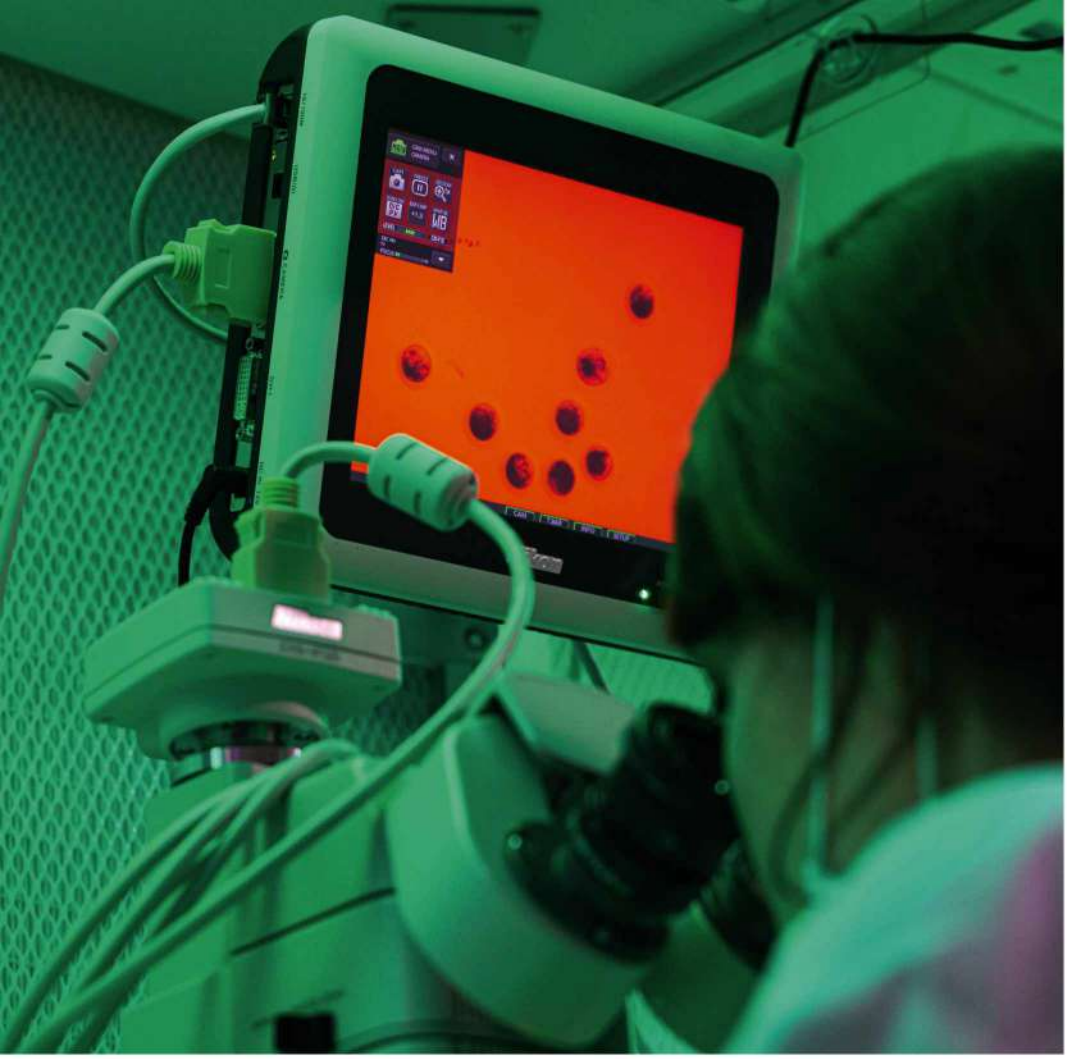
All of the northern white embryos created so far come from just three 'parent' animals; one female and two males. Any calves would be siblings or half-siblings. They would never be allowed to mate with each other for fear of inbreeding. To make healthy, genetically diverse embryos, the scientists need more eggs and more sperm from other, non-related rhinos, and it's here that some innovative cell biology comes in.

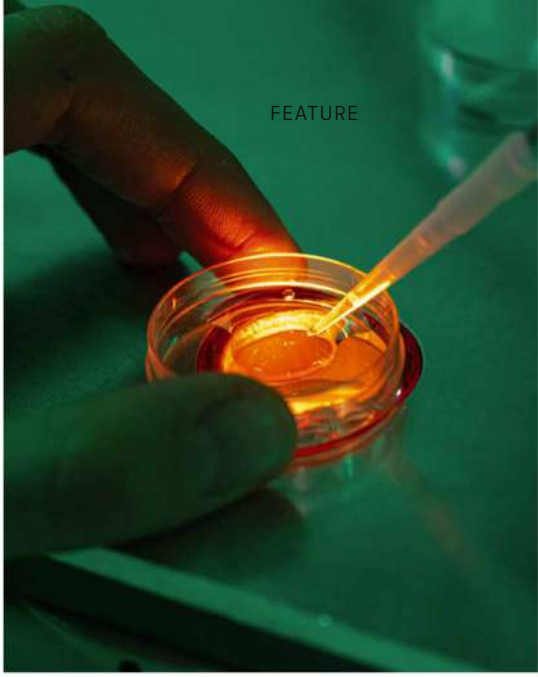
For more than 40 years, conservationists have been collecting and freezing living cells from all manner of endangered species. They're an invaluable research resource, and increasingly a source of raw material for assisted reproductive technologies. The 'Frozen Zoo', run by the San Diego Zoo Wildlife Alliance, contains over 70,000 samples from more than 700 species, including skin cells from 12 different northern white rhinos; eight unrelated individuals and four of their offspring.

In 2011, cell biologist Dr Jeanne Loring from the Scripps Research Institute, California, showed that these skin cells can be 'reprogrammed' to become stem cells. Stem cells are versatile shape-shifting cells, with the potential to generate many other cell types. Then, in December 2022, a different group of researchers, this time from Japan, showed that these stem cells can be coaxed to become the precursors of egg and sperm.

Put simply, the research suggests that rhino eggs and sperm could be grown in the lab, using frozen, decades-old skin cells as the

MATJAZ KRIVIC/INSTITUTE ARTIST X3, SHUTTERSTOCK X2





Over these pages, you can see the scientists at work in a specialist lab in Italy, where they are creating northern white rhino embryos via IVF. Already, 24 embryos have been created, and have been frozen in liquid nitrogen to be implanted in a surrogate rhino mother in the future

starting point. This means that when Fatu is retired as an oocyte donor, they will have other sources of oocytes. More research is needed to persuade these early egg and sperm cells to morph into their mature forms, but this really could be a game changer.

Loring points out that there is more genetic diversity in the 12 northern white rhino samples that are frozen away, than exists in the entire living population of southern white rhinos, who, she says, "are doing just fine." Scientists have the cells required to create a viable northern white rhino population, and increasingly, they have the methods required to make it happen.

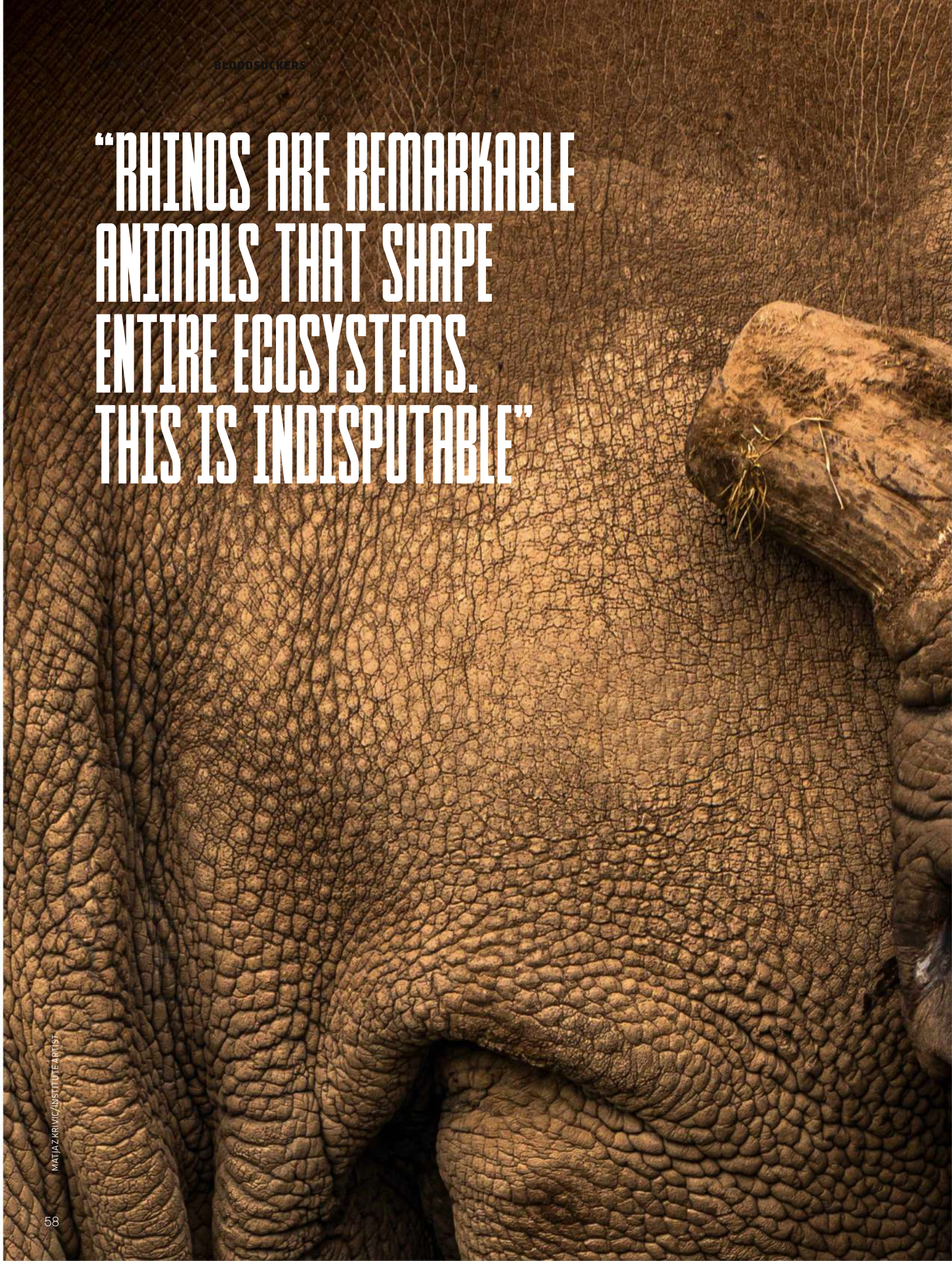
The long-term goal is to reintroduce viable populations of northern white rhinos into the wild, where they would act as ecosystem engineers. By mowing the grass, African rhinos create the 'grazing lawns' on which species like impala and wildebeest depend. When the fires come, these closely-cropped patches act as natural firebreaks, providing safe havens for fire-intolerant plants and slow-moving animals. Rhino dung returns nutrients to the ground. Their ticks provide food for birds, such as oxpeckers. When they wallow, they create and maintain waterholes. Rhinos are remarkable animals that shape entire ecosystems. This is indisputable, and yet, not everyone is in favour of the northern white rhino's return.

LET IT GO?

A key criticism of the BioRescue programme is that it's too expensive, and that funding would be better spent protecting other rhino species, such as the black rhino in Africa or the Indian rhino in Asia. These species are threatened, and their numbers are depleted, but not to the extent where they require assisted reproductive techniques to save them. The BioRescue programme is unavoidably expensive. It's primarily funded by the German science ministry, with a six-year grant approximating €6m (£5.25m approx), but Hildebrandt points out that the programme is not competing with other conservation missions, or diverting funds from them.

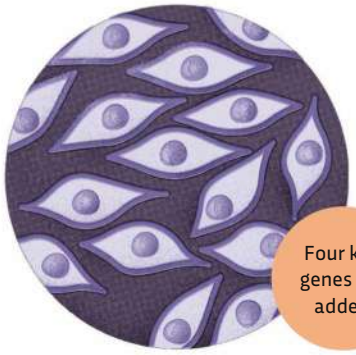
Another argument is that the project sets a dangerous precedent; that it's okay to let species dwindle to the brink of extinction, because we can always bring them back later. "But it's not okay," says Hildebrandt. "No one is advocating that. →

"RHINOS ARE REMARKABLE ANIMALS THAT SHAPE ENTIRE ECOSYSTEMS. THIS IS INDISPUTABLE"



MATJAZ KRIVIC/INSTITUTE ARTIST

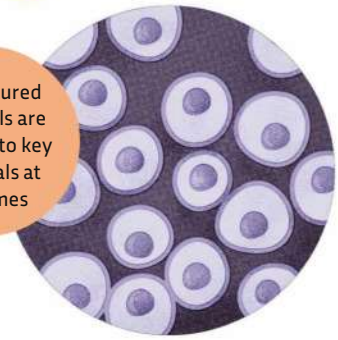
HOW TO GROW A RHINO



1. A biopsy is taken from the rhino. It contains connective tissue cells called fibroblasts. They are grown in culture.

Four key genes are added

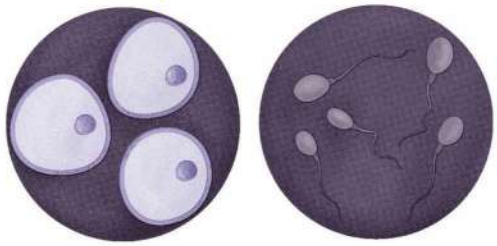
2. The addition of the key genes causes the skin cells to be reprogrammed into 'induced pluripotent stem cells'. These have the potential to generate many other cell types.



The cultured stem cells are exposed to key chemicals at key times

3. The cultured stem cells turn into precursors of eggs and sperm. These small, immature cells still contain a double set of chromosomes (mature eggs and sperm only have a single set of chromosomes).

These precursor cells need to mature and go through a special type of cell division, called meiosis, in order to lose one set of chromosomes. The exact conditions needed for the last step are currently unknown, but it's thought that the cells will need to be cultured alongside other reproductive tissues.



4. When mature, the eggs and sperm will be fully functional sex cells and could be used for IVF and other assisted reproductive technologies.

ABOVE Researchers have discovered that skin cells can be reprogrammed to become stem cells, which can then be coaxed into immature sperm or egg cells

→ We need to be aware that this is something we cannot do routinely for each species, precisely because it is so costly."

Others feel that the time has come to let nature run its course, and let the northern white rhino go. To do otherwise, they say, would be 'playing God'.

"It's an interesting argument," says ethicist Prof Ronald Sandler from Northeastern University, Boston. "It suggests that this is a place where our agency doesn't belong, and speaks to a broader question about our role in the conservation context."

He argues that traditional conservation methods, such as captive breeding, creating reserves and preventing poaching, are about undoing human impacts. This work is not so different. The methods may be novel, but they're still about undoing the damage that our species unleashed when it began to hunt and kill and the northern white rhino.

THE FINAL COUNTDOWN

There's one final argument, however, that is more difficult to counter. The northern white rhino is *Ceratotherium simum cottoni*. The southern white rhino is *Ceratotherium simum simum*. They are not two separate species. They are separate subspecies, which is a term used to denote populations that are genetically similar but geographically distinct. They went their own separate ways around 80,000 years ago when one population headed north, and another headed south. They look 'more or less' the same, they behave 'more or less' the same, and genetically, they are 'more or less' the same. The small differences that do exist may well turn out to be important, but in the absence of any scientific data to support this idea, why, some argue, waste resources saving the northern white rhino when it's almost indistinguishable from its southern counterpart?

RIO THE PHOTOGRAPHER/BIORESCUE X2. ILLUSTRATION: DANIEL BRIGHT

TOP Stem cell scientist Dr Vera Zywitza has successfully created rhino stem cells from skin cells

ABOVE Prof Thomas Hildebrandt and colleagues collecting oocytes (immature egg cells) from Fatu

"OTHERS FEEL THAT THE TIME HAS COME TO LET NATURE RUN ITS COURSE, AND LET THE NORTHERN WHITE RHINO GO. TO DO OTHERWISE WOULD BE 'PLAYING GOD'"

Ecologist Dr Jason Gilchrist from Edinburgh Napier University goes one step further. He's worked in Africa, and has helped to relocate rhinos from dangerous to safe regions. "Given the effort and cost needed to resurrect the northern white rhino, I think it would be more practical to translocate southern white rhinos into the areas where we'd like northern white rhinos to be, and then let natural selection do its job," he says.

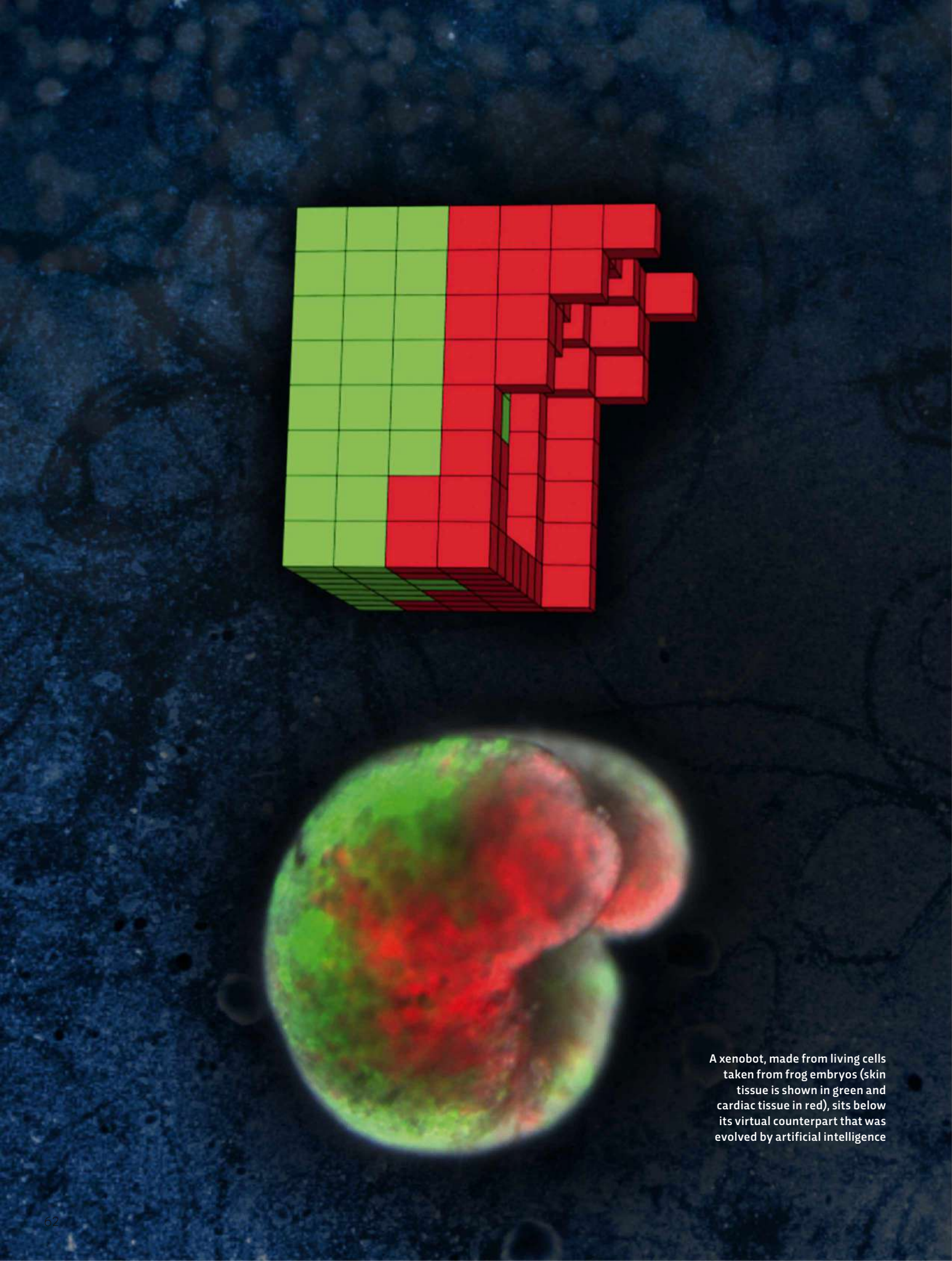
In time, he argues, evolution could delicately sculpt the southern white rhino into something that more closely resembles its northern relative. It's an option, but if conservation is in the business of saving species, shouldn't it be in the business of saving subspecies too?

There's another important reason why the work of Hildebrandt and colleagues is so very valuable. By perfecting their methods in one endangered species, it paves the way to do it in others. Hildebrandt's methods are already being employed to collect semen samples from other endangered mammals, including tigers and pandas. He's working to perfect egg retrieval and embryo implants in elephants, while Loring has reprogrammed skin cells from an endangered African monkey species called the drill.

Meanwhile, Najin and Fatu are getting older. There are fewer than 76 Javan rhinos, and 50 Sumatran rhinos left in the wild. Hildebrandt believes these methods could help them, and other endangered species. "Of course, we'd rather that they didn't need this kind of intervention in the first place," he says, "and yet, here we are." **SF**

by **DR HELEN PILCHER**

Helen is a freelance science writer and presenter, with a background in cell biology. Her latest book is Life Changing: How Humans Are Altering Life On Earth *(£10.99, Bloomsbury Sigma).*



A xenobot, made from living cells taken from frog embryos (skin tissue is shown in green and cardiac tissue in red), sits below its virtual counterpart that was evolved by artificial intelligence

HERE COME THE XENOBOTS

Scientists are using living materials to make machines that some would regard as alive... and now they've started to replicate

by HAYLEY BENNETT

When we think of a robot, what usually comes to mind is some kind of synthetic servant – a metal-clad machine controlled by electronics. While it might do chores for us and perhaps even talk to us in ways that seem intelligent, we wouldn't regard it as alive. But what if, instead of building robots out of hard, lifeless materials, we built them out of the soft materials that nature relies on? What if we built them out of cells?

This is exactly the approach that researchers in Prof Josh Bongard's lab at the University of Vermont in the US are taking. For the last four years, they have been designing and creating 'xenobots': miniature machines made from living frog cells. Bongard explains the team's approach: "[If you] make a robot out of metal and plastic … the pieces themselves have no intelligence. We're approaching robotics in a completely different way. We're building from components that are themselves fantastically intelligent machines."

Nature has been inspiring robotics for decades. It's led to actuators based on real muscles that allow robots to move more easily. Elsewhere, pads that mimic geckos' feet let robots climb vertical glass. Xenobots, by contrast, are made from nature's own building blocks. According to Dr Victoria Webster-Wood, an expert in biologically inspired robots at Carnegie Mellon University, this type of approach "enables us to directly harness living materials' natural adaptability."

What's fascinating about Bongard's xenobots is that they can be made from normal cells taken from frog embryos – no genetic tweaks required. Although scientists already knew these cells could move on their own, in this case they're being used as materials to generate predictable, robot-like behaviours, such as herding particles around a Petri dish, cooperating like sheepdogs and even birthing balls of other cells that might be regarded as xenobot babies.

ARTIFICIAL SELECTION

While it's not clear what it is in the xenobots' internal workings, or rather those of the frog cells, that make them behave in this way, their capabilities do make them potentially useful for all manner of tasks. Cleaning-up microplastics, for example, or, as the researchers outlined in their first paper on the xenobots, published in 2020, crawling to the site of diseased tissues in humans to help restore them to health.

So if you're going to make a xenobot, where do you start? Well, the Vermont team starts in a virtual Petri dish, on a computer, where an artificial intelligence (AI) program 'evolves' bunches of frog cells, based on their shape, to perform whatever task it is the scientists are interested in. "It creates a population of virtual xenobots, deletes the ones that do a poor job and makes randomly modified copies of the survivors," explains Bongard.

The scientists tell the AI how many rounds of this artificial selection process to complete and in a just a few seconds, they have their design. As an example, that design might be a ball of cells with a hole in the middle, like a pouch, which works well for transporting objects.

It's the AI-based design process that's the "real masterpiece" of the team's approach, according to Dr Falk Tauber, a bio-inspired technology expert based at the University of Freiberg in Germany. Without the virtual Petri dish, he notes, testing hundreds of different cell configurations could take weeks or even months using real cells. "This not only represents an immense time advantage, but also provides the opportunity to implement only the most promising approaches that have proven successful in [the computer]," he says.

He suggests the AI approach could be useful in other scenarios too – like rapid design →

SAM KRIEGMAN X2

"THE XENOBOTS ARE STARTING TO BLUR THE LINE BETWEEN LIVING AND NON-LIVING, REIGNITING THE DEBATE ABOUT WHAT IS LIFE"

TONY LUONG/NEW YORK TIMES/REDUX/EYEVINE, SAM KRIEGMAN X2

→ of personalised organ transplants that precisely fit a patients' anatomy.

Then comes the time-consuming bit, as the virtual designs have to be transferred to the real-life cells. It's a process that takes the team's sole xenobot sculptor, biologist Dr Doug Blackiston, based at Tufts University, Massachusetts, hours for each millimetre-scale xenobot. Using microsurgery instruments, Blackiston painstakingly carves the shape designed by the AI into tissue harvested from frog embryos. "For me, it's a lot like drawing or working on art," he says, adding that he enjoys seeing the shapes come together. However, he admits that for the xenobots to find real-world applications, they'll need to speed up the process to create more than the current 30 to 40 xenobots a week. That advance could come from 3D printing, which can use cells and tissues as printing 'inks'.

PUSHING TO PROGRESS

The xenobots then spend a little over a week crawling or swimming around a dish before disintegrating (as they don't eat, their lifespan is limited). In their original experiments, the researchers made 'walking' xenobots from combinations of heart and skin cells; the piston-like action of heart cells translated into movement. Now, though, they use skin cells, taking advantage of beating hair-like structures called cilia, which protrude from the outer surface of the balls of cells, allowing them to 'swim'.

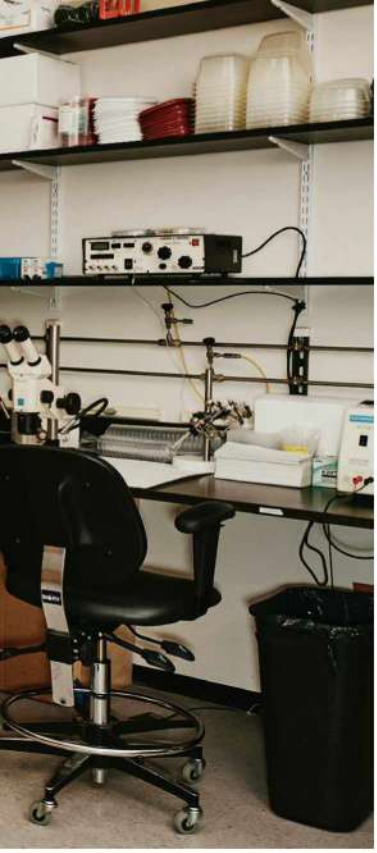
After initially seeing their movements, the researchers thought the xenobots might be capable of pushing things around, though they wondered if the xenobots would be strong enough. "I started with very light dye particles, littered across the bottom of the Petri dish like a fine layer of ash or snow," says Blackiston. "I happened to get lucky on the first try and it worked." The xenobots could also push tiny glass beads around.

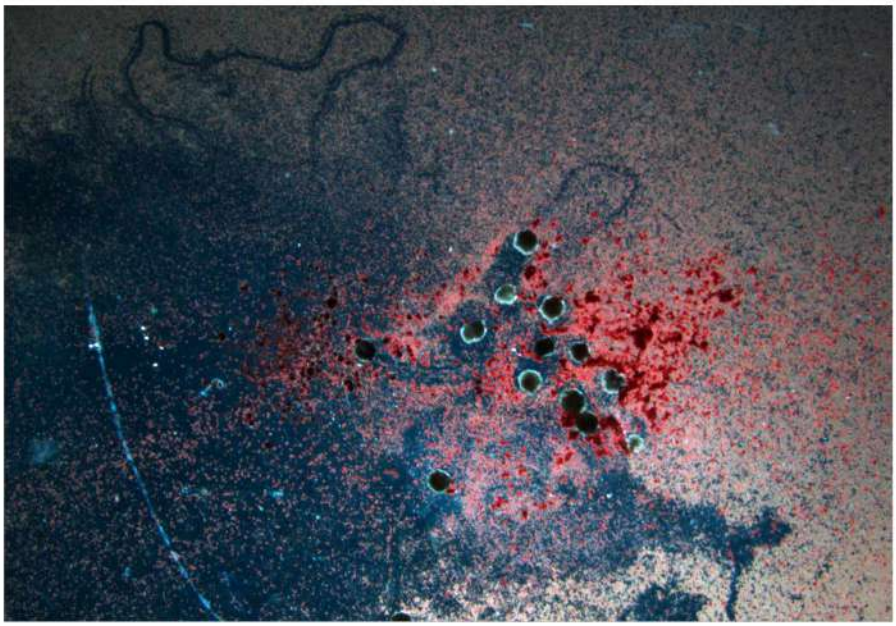
After the researchers progressed to making the swimming xenobots, they started giving swarms of them more interesting things to move around, like cells – the same cells of which the miniature robots themselves are composed. That was when something intriguing began to happen: the swarm began pushing the cells into little piles. Frog cells are sticky so the piles tended to stay together and then, a few days later, hairs started to appear on their surface – cilia, just like on the surface of the xenobots. "And then," says Bongard, "Doug [Blackiston] noticed that a couple of them started to move." At this point, it was clear that the xenobots were making more of themselves. It wasn't a traditional 'have sex, make a baby' type of scenario, but it was a form of replication that had never been seen in nature.

According to Blackiston, he knew the experiment would work if he could get the conditions right. But that didn't make it any less exciting when he first showed Bongard and the team one of the 'children' moving around on a Zoom call. "It was silent on the call – the biologists, the computer scientists," Bongard remembers. "You know, self-replication is kind of a dream and a hope [for] machines in general and to see it… it completely blew my mind."

When the researchers realised their xenobots could self-replicate, they told their AI to evolve versions that could do it better. The AI set to work, designing a shape that looked pretty familiar: Pac-Man, or as Bongard puts it "a shovel, basically", which makes sense when you're making your babies by pushing bits of them into piles. You can see this Pac-Man-like shape in the headline of this article.

The fact that the xenobots are now capable of self-replication opens up a whole suite of potential applications, Bongard says, due to what he calls "exponential utility". The concept applies to any technology that does something useful and becomes more useful the further it spreads. Environmental clean-up is a good example, as well as vaccines, or technologies that could put out forest fires. These technologies don't spread on their own, though, so they could benefit from a self-replicating carrier to help them. Although this is all just a theory, the researchers did





TOP LEFT Biologists Doug Blackiston (seated) and Michael Levin help turn the AI's xenobot designs into reality

ABOVE A group of xenobots 'tidying up' a Petri dish by moving debris around and collecting it into a pile

show through computer modelling that if they fed the xenobots enough cells and they continued to replicate, then the xenobots use for a simpler application, such as moving wires around in a circuit, would continue to grow.

If self-replicating xenobots sound like the sort of sci-fi movie scenario we ought to avoid, the thing to remember is that the parent bots can only produce offspring under certain circumstances, which, as Webster-Wood points out, the researchers control. Without access to additional free-floating cells, they can't replicate at all. Plus, the team's xenobots are biodegradable and 'die' in a matter of days. As Tauber puts it, "These small cellular robots are safely housed in the laboratories of Bongard's team and could not 'live' in the outside world."

LEFT Xenobots are tiny. Here a few can be seen dotted around the centre of a real-life Petri dish sitting on a $1 bill

In fact, 'living' is not a label Tauber would apply to them at all, precisely because their survival depends on such specific conditions. Bongard, though, believes that along with other technologies – like biohybrids that combine organic and technological components – the xenobots are starting to blur the line between living and non-living, reigniting the debate about what is life.

Meanwhile, the xenobots' behaviour has sparked other questions. For example, the researchers don't know whether the xenobots are really cooperating when they push cells and other objects around together. Are they able to sense each other through the millions of different receptors that exist on the surface of living cells? Or are they just mindlessly moving around like wind-up toys?

Another intriguing question, of course, is whether biological robots could also be made from human cells – and whether it's a route the team is planning to take. It's certainly on the to-do list, according to Bongard. "You know, frog and human cells diverged not that long ago, when you think about the total evolutionary history of cells," he muses, suggesting that, in principle, it should work. Xenobots from human cells would be more compatible with medical applications, though there would be a long road to get them approved.

In the meantime, the researchers want to discover more about what it is in the frog cells' underlying biology that makes them behave as they do. They hope to learn how to better manipulate the living materials to create better machines. That's something their AI is figuring out, but can't communicate to them yet. "We're asking the AI to make machines, but the repercussion of that is, along the way, the AI is learning more and more about biology," says Bongard. A key part of the work, he adds, is getting the AI to explain what it has learned about biology back to "us poor humans". **SF**

by HAYLEY BENNETT
(@gingerbreadlady)
Hayley is a freelance science writer specialising in biology, chemistry and the environment.

I'LL JUST CLOSE MY EYES FOR A MINUTE...

Feeling tired? Us too. For many, a good night's rest is hard to come by, with sleep disorders and deprivation at all-time highs. So are we sleepwalking into a national health crisis, or can something be done?

by CATHERINE OFFORD

ILLUSTRATION: JIAQI WANG

There's no denying it: my New Year's resolution hasn't gone well. Just weeks into 2023, I've yet to catch up on what feels like months of lost sleep to become a healthier, more energetic super-being. My consolation, each dark winter morning as I reach for the snooze button rather than the gym clothes, is that at least it's not just me.

In a YouGov poll of adults in Great Britain, published at the beginning of last year, one in eight people said they felt tired "all the time", and a further quarter were tired "most of the time". Parents of kids under 18 were the weariest of them all, but childless adults and parents of older children reported feeling wiped out too. Asked about what they'd give for some extra shuteye, roughly half of people polled said they'd opt for another hour of sleep instead of £20 in cash, while more than a third would choose it over sex.

A simple explanation for all this tiredness is that we're not getting enough time in bed. Surveys suggest that some 40 per cent of British adults are regularly getting less than the minimum seven hours of sleep recommended by the NHS. Around 5 per cent report getting four hours or less – a level of sleep deprivation that can have dangerous consequences: one study found that people driving after less than four hours sleep had a more than 10-fold increased risk of road accidents compared to drivers who got at least seven.

The long-term view isn't any better. Research has linked sleeping less than the recommended minimum to an elevated risk of myriad chronic diseases, including diabetes, cancer, heart disease, depression and dementia. Such is the concern about this apparent sleeplessness epidemic that organisations like the Royal Society for Public Health have called for a national →

→ sleep strategy and better public education about how much we should be aiming for.

Yet while there's clearly such a thing as too little sleep, studies of sleep duration don't tell the whole story. Contrary to popular perception, there's scant evidence that we're averaging less slumber now than in the past, says Prof John Groeger, a psychologist at Nottingham Trent University. Using surveys, he and his colleagues found that Brits in the early 2000s were clocking just over seven hours a night on average – roughly what people said they were getting in the 1960s.

Although self-reported data need interpreting with caution, surveys in other countries have turned up similar findings, detecting small or no reductions in the average amount of sleep over time. Research on so-called 'pre-industrialised' societies challenges the idea that our ancestors spent more time snoozing, Groeger says. A 2015 study that monitored sleep patterns in rural communities in Bolivia, Namibia and Tanzania found that adults tended to get between 5.7 to 7.1 hours a night.

"WHILE YOU MIGHT IMMEDIATELY ATTRIBUTE DOPINESS DURING THE DAY TO A ROUGH NIGHT, YOU MIGHT NOT THINK TO BLAME YOUR EATING HABITS ON A BAD SLEEP, TOO"

HOW MUCH SLEEP DO WE NEED?

While seven hours is a sensible minimum to aim for, scientists don't know exactly how much the average person in 2023 needs, says Prof Kenneth Wright, a sleep and circadian scientist at the University of Colorado Boulder. The amount we require can be affected by genetics and lifestyle, and changes as we age. Crucially, too, "sleep duration is only one component of sleep health. The timing of our sleep is important, the regularity of our sleep is important, the quality of that sleep is important."

ALAMY

LEFT Using your phone at bedtime can lead to too much mental stimulation

LEFT Daytime tiredness could simply be due to too much alcohol, or not enough exercise

Rather than fixating on how much we're getting, experts suggest that people pay attention to how they feel when they're awake. A bit of grogginess is normal after a wild night out. But repeatedly dozing off during the day or feeling washed out for days at a time could signal a problem, says psychologist Michael V Vitiello, a Professor Emeritus at the University of Washington who studies sleep and sleep disorders in ageing.

In some cases, these symptoms could mean a sleep disorder or an underlying health condition. According to the NHS, around one-third of the population will experience insomnia – consistent difficulty falling and staying asleep – at least once. The disorder is likely underdiagnosed, says Dr Suzanne Bertisch, a sleep researcher and physician at Brigham and Women's Hospital and Harvard Medical School. Unfortunately, she adds, extreme exhaustion can make it harder to recognise you're exhausted.

Stress, illness and disruption caused by COVID-19 may have led more people to struggle with insomnia, at least in the short-term. Vitiello and others found that, while worldwide cases of severe and moderate insomnia stayed fairly level in 2020 and 2021, the number of people reporting mild, or 'subthreshold' symptoms went up. Obstructive sleep apnoea, a disorder where soft parts of the throat flop over airways and temporarily interrupt breathing, also seems to be on the rise in the UK. Doctors have linked this increase to growing rates of obesity, which makes airway obstruction more likely.

Of course, daytime tiredness doesn't always signal a sleep disorder: you might just be suffering the effects of a Western lifestyle. For example, alcohol might make people fall asleep faster, but also messes with the structure of your sleep. A drink or two close to bedtime can lead to less rapid-eye movement (REM) sleep – the phase typically associated with dreaming – and more awakenings during the night.

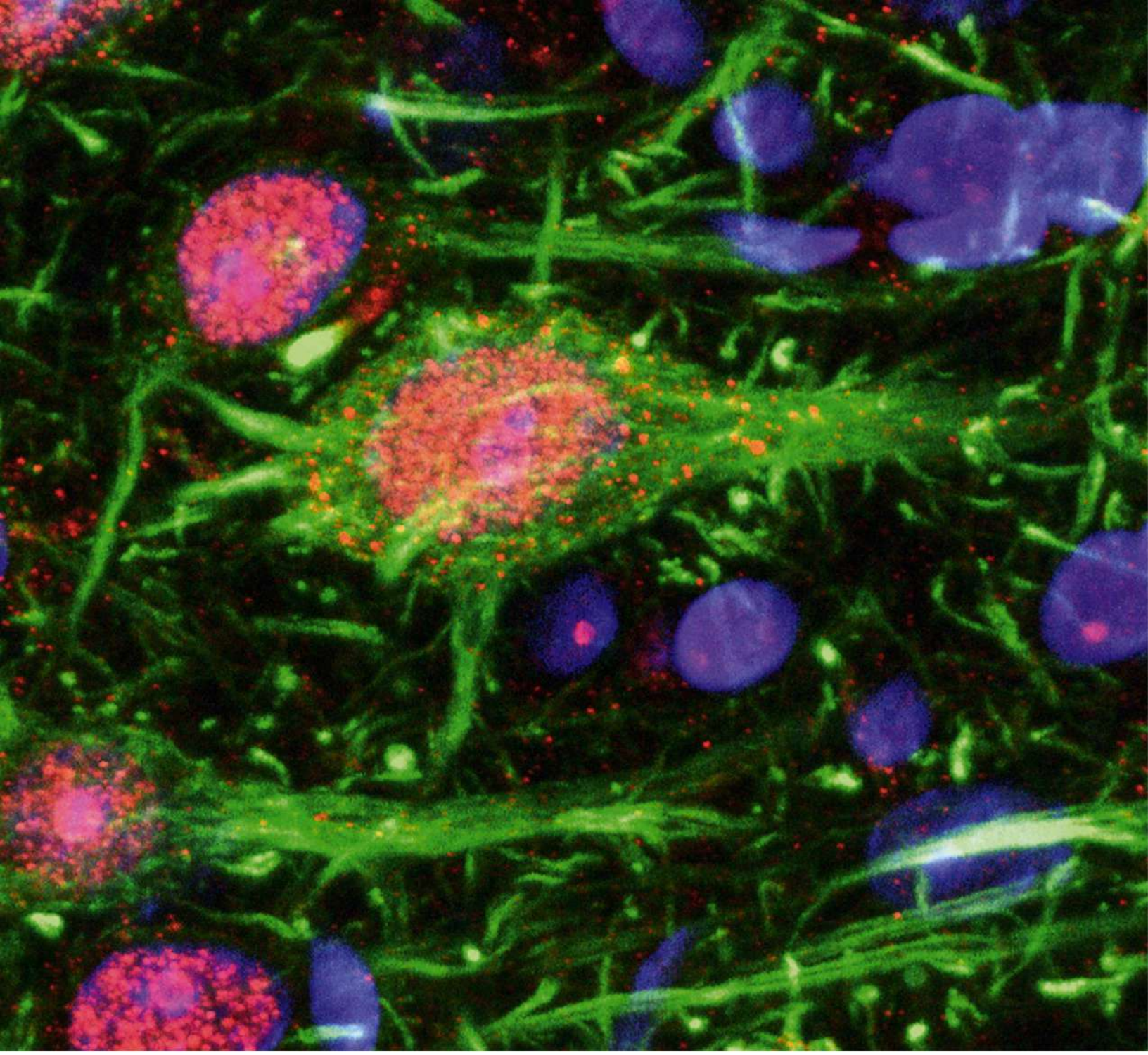
Mobile phones, which some three-quarters of Britons admit to keeping in their bedrooms overnight, have a lot to answer for, too. Both the light from an electronic device's screen and the mental stimulation from the information you're scrolling through can contribute to poor sleep, Groeger says. On top of this, many people have to deal with work demands or caring duties that make it all but impossible to get an uninterrupted night's rest.

Whatever the cause of sleep disruption, the verdict remains the same: it's affecting how the rest of your body functions, and not always in the ways you expect. For instance, while you might immediately attribute dopiness during the day to a rough night, you might not think to blame your eating habits on a bad sleep, too. Yet studies have revealed that sleep deprivation can alter the hormonal and neural pathways controlling appetite and fat storage, and may promote overeating and weight gain.

Newer research is turning up a string of connections between sleep-regulating brain circuits and the immune system, the waste-clearance systems in your body's organs and even the bacteria living in your gut. "We're just beginning to understand how interactions among these systems work," Wright says.

GETTING BACK TO SLEEP

Unsurprisingly, the high prevalence of sleep complaints and our worry about them has been a boon to the field of sleep medicine and the industry built around it. An estimate by one market research company last year valued the global sleep aids market, with all its medicines, supplements, diagnostic devices and specialised mattresses at some $65bn (£52bn approx). Many of these products have little or no scientific data to back them up. For instance, while anecdotal evidence has highlighted possible benefits of herbal and dietary supplements such as valerian and melatonin, the clinical evidence is underwhelming. →

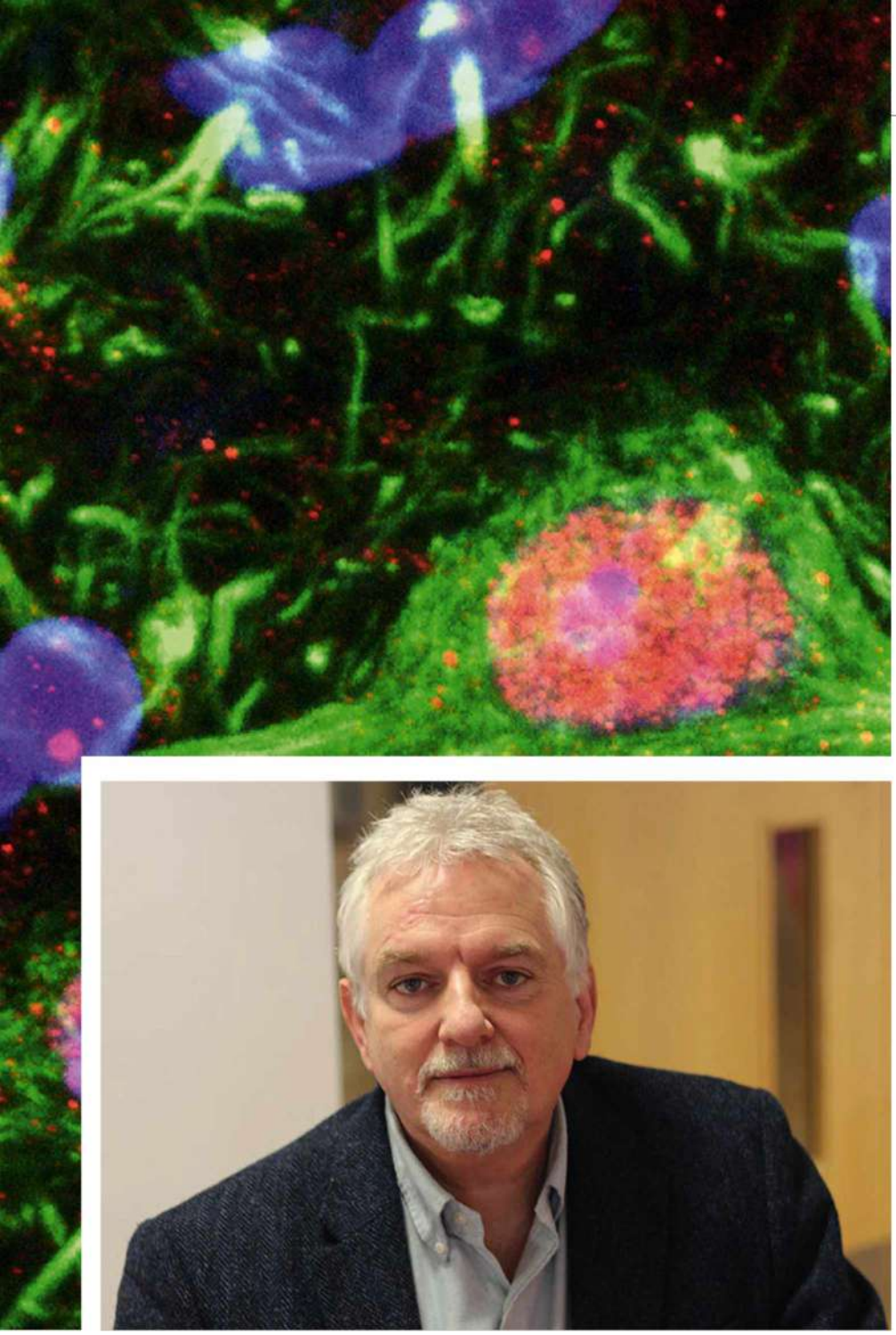


SCIENCE PHOTO LIBRARY, NOTTINGHAM TRENT UNIVERSITY

"THERE HAVE BEEN SOME MAJOR IMPROVEMENTS IN SLEEP TREATMENTS IN THE LAST FEW YEARS"

→ Most of the supplements that are available over the counter are useless for improving your sleep, Vitiello says (although melatonin can help lessen jet lag). "They're placebos. If you're taking them and you think they're improving your sleep, that's just fine, carry on. But just recognise that there's no data to support their use."

That said, there have been some major improvements in sleep treatments in the last few years, especially for people with clinically diagnosed disorders, says Bertisch, who has consulted for companies developing therapies. Insomniacs have often been given sleep-inducing sedatives to help them doze off, but a new class of prescription drugs called orexin receptor antagonists instead target the brain circuits that keep the body



MAIN IMAGE The chemical messenger orexin binds to orexin receptors (red) in the brain, inducing wakefulness

awake. Specifically, they block the effects of orexin, a chemical messenger that keeps you alert, thus making it easier to fall asleep. Researchers suggest that this kind of treatment will be less likely than older medications to cause side-effects such as confusion or memory problems during the day. The latest, daridorexant, was approved in 2022 in the US and EU for patients who have been suffering with insomnia for at least three months. It's scheduled to become available in the UK later this year.

Cognitive behavioural therapy, a treatment that helps people identify and change unhelpful behaviours and thought patterns, has also repeatedly shown benefits in clinical trials of insomnia patients, Bertisch says. Therapy doesn't have to be face-to-face with a psychologist: an app called Sleepio that's been shown to

INSET Prof John Groeger has found Brits are averaging seven hours of sleep a night

be effective in reducing insomnia was made available through the NHS last year. People with sleep apnoea have more options than before too, with new breathing-aid devices to help keep their airways open – though doctors often first recommend weight loss when the condition is linked to obesity.

LIFESTYLE CHANGES

If a sleep disorder isn't what's causing your tiredness, you're most likely to see benefits from changing your lifestyle. Getting lots of light during the day can help keep your body clock on track, making it easier to get into a regular sleep rhythm and feel better when you're awake, says Wright. He and his colleagues recently published recommendations on daily light exposure, including advice to dim light levels in the three hours before bedtime and to make your sleeping environment as dark as possible.

Other commonly recommended habits – doing regular exercise, limiting caffeine, trying to get up at the same time each morning and avoiding work and stress close to bedtime – may be boring, but research shows they're likely to be effective, says Groeger. Clinical trials have found that getting people to do bouts of weight training, aerobics or other physical activity often leads to moderate improvements in sleep quality, for example. Although most of these studies are based on participants' subjective reports of how well they slumbered, some use brain-monitoring equipment that tracks how often sleep is interrupted and assesses sleep structure.

These recommendations also tap into a popular idea in the research community: that timing, not just of sleep but of daily activity and rest more generally, plays a critical role in human health. Wright is one of many researchers currently working on this idea. His lab has found that the damaging effects of shift work – a notorious sleep disruptor linked to increased risk of cancer, diabetes and other chronic conditions – may stem partly from disruption to the normal timing of meals and knock-on effects on metabolism and the immune system. A better understanding of these daily rhythms could help scientists →

"WHILE IT'S IMPORTANT TO PRIORITISE GOOD SLEEP, THERE'S NO NEED TO DIVE INTO DATA FROM SMARTWATCHES"

→ develop new therapies, says Wright, who has consulted for the UK-based pharmaceutical company Circadian Therapeutics. "That may afford us opportunities to go ahead and manipulate those systems to improve health."

In the meantime, one thing experts recommend you don't do is obsess about your shuteye. That might sound like a tall order, given all of the above. But while it's important to prioritise good sleep, there's no need to dive into data from smartwatches or phone apps to try to understand every minute of every night.

Many personal trackers produce unreliable data anyway, particularly for anything more complex than sleep duration, says Bertisch. When it comes to delineating sleep stages, for example, scientists will use brain monitoring, eye tracking, and other tech to determine when someone is dozing off, when they're dreaming, and so on. Wrist-worn gadgets instead rely on proxies such as heart rate and how much you're tossing and turning. The results are laughably inaccurate by comparison, she says.

Poring over this information can have the opposite effect you want it to, Bertisch adds. Physicians "have seen the downside of people becoming obsessive and concerned about their sleep –

MILESTONES IN SLEEP MEDICINE

1700s

Demand for 24-hour labour in mills and forges in Britain boosts the use of shift-workers. Centuries later, this kind of disruption to the body's daily rhythms will be linked to an elevated risk of myriad chronic diseases. ↓

1834

Scottish physician Robert Macnish publishes his ideas about slumber in *The Philosophy Of Sleep*. He notes the negative effects of coffee, anxiety and excessive heat and recommends "plenty of exercise in the open air."

1880s

The first electric lighting systems are installed in houses in the UK, giving people control over the dark-light cycles in their homes.

1913

French physician Henri Piéron publishes *The Physiological Problem Of Sleep*. The text marks the beginning of modern-day approaches to sleep research and medicine. ↓

1925

Physiologist Dr Nathaniel Kleitman (pictured sitting alongside the bed), known as the father of modern sleep medicine, sets up the first lab exclusively devoted to the study of sleep. ↓

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and actually causing worse sleep problems, because they're worried about it."

Researchers say it can be helpful instead for people to seek out behavioural tricks or habits that work for them, whether that's reserving time at night for winding down or getting outside first thing in the morning. Establishing a routine that you can stick to is key, Vitiello says.

"The simplest advice I can give is: get regular sleep time with regular hours and really don't vary very much." And try, he adds, to get rid of the bad habits. "Pepperoni pizzas in bed just before you go to sleep are probably not the way to go."

Now there's a New Year's resolution. SF

by CATHERINE OFFORD

Catherine is a journalist reporting on stories in science, medicine and policy.

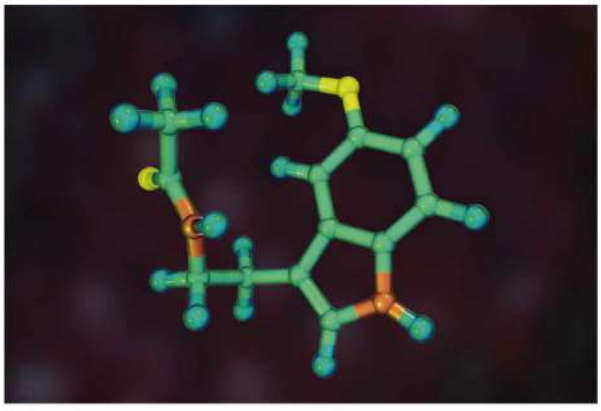
RIGHT Prioritise good sleep by establishing a bedtime routine

1929

German psychiatrist Hans Berger (pictured) 'discovers' electro-encephalography, or EEG. Using his 15-year-old son as a test subject, he makes the first recordings of human brain waves. The first waves he sees are with his son's eyes closed, so he calls them alpha waves. His son opens his eyes, and he notices a different signal that he names beta waves. ↓

1958

Aaron Lerner, an American dermatologist, identifies the hormone melatonin, which helps regulate sleep-wake cycles in mammals. The compound will later be used as a medication to mitigate jet lag. ↓



1965

Obstructive Sleep Apnoea (OSA) is defined. ↓

1970s

Various researchers start to uncover the genes regulating mammals' daily, or circadian, rhythms. The findings, which will go on to garner a Nobel Prize, pave the way for new research into why we sleep and why we wake.

2007

The first iPhone hits the market. Researchers will later find that light from smartphones and other devices can disrupt sleep quality. By 2022, three-quarters of Britons will say they keep their phone in arm's reach overnight. ↓

2014

The US Centers for Disease Control and Prevention (CDC) describes insufficient sleep as a "public health epidemic", amidst the accumulation of research linking a lack of sleep to an increased risk of long-term health problems.

DON'T JUST READ THIS MAGAZINE... LISTEN TO IT, TOO

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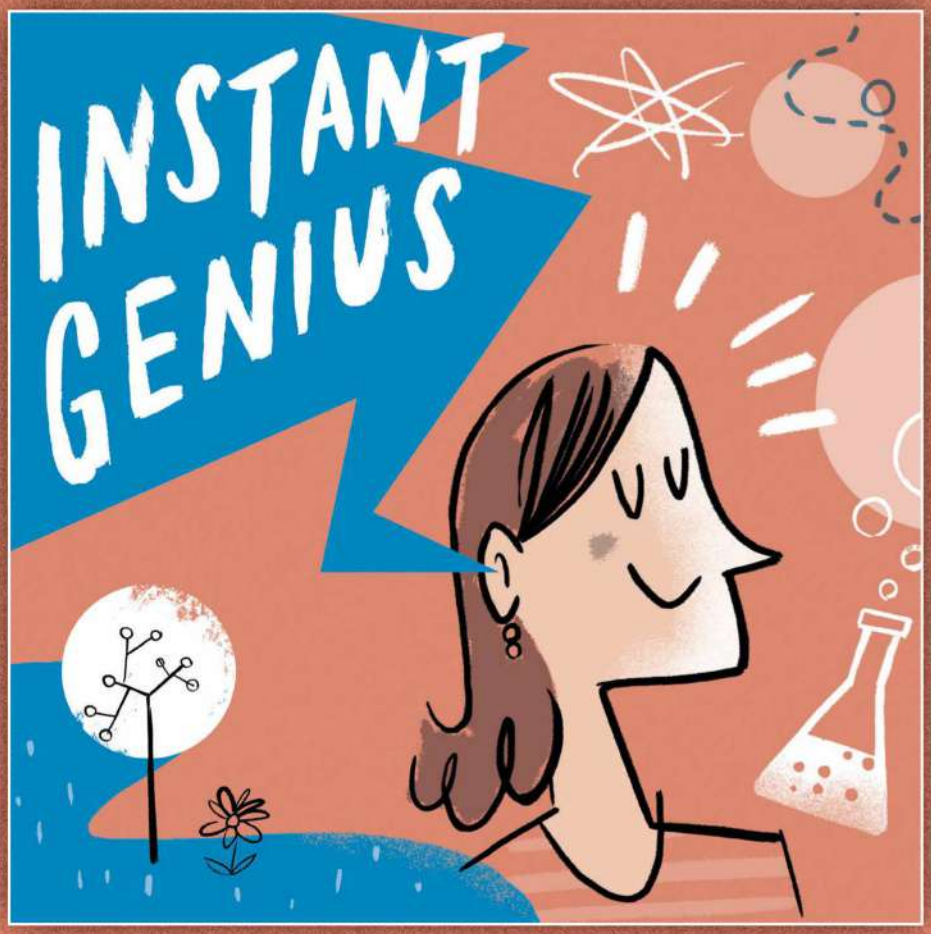

FEATURING

CHATGPT
with ***Dr Sam Illingworth***

EMOTIONS
with ***Dr Dean Burnett***

FORENSIC SCIENCE
with ***Prof Dame Sue Black***

VITAMIN D
with ***Dr Gail Rees***

Q&A

YOUR QUESTIONS ANSWERED

... WHEN YOU'RE HAVING A CAST REMOVED, WHY DOESN'T THE MACHINE CUT YOUR LIMB?
... IS CHEWING GUM BIODEGRADABLE?
... WHAT IS FREEZER BURN, AND SHOULD YOU STILL EAT THE FOOD?
... DOES THE BRAIN REALLY EXPERIENCE A 'GREAT RESTRUCTURING' AFTER WE TURN 40?
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... WHY DO TEENS HAVE DIFFERENT SLEEPING PATTERNS FROM ADULTS?
... AM I PSYCHIC?

Email your questions to

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OUR EXPERTS

PETE LAWRENCE Astronomy expert	**AMY ARTHUR** Science writer	**DR NISH MANEK** GP and medical expert
DR CLAIRE ASHER Science journalist	**DR HELEN PILCHER** Biologist and science writer	**DR EMMA DAVIES** Science writer
PROF ALICE GREGORY Psychologist and sleep expert	**PROF PETER BENTLEY** Computer scientist	**DR CHRISTIAN JARRETT** Psychologist and author
DR ALASTAIR GUNN Astrophysics lecturer	**PROF TREVOR COX** Acoustics expert	**PROF STEVE BRUSATTE** Veteran palaeontologist

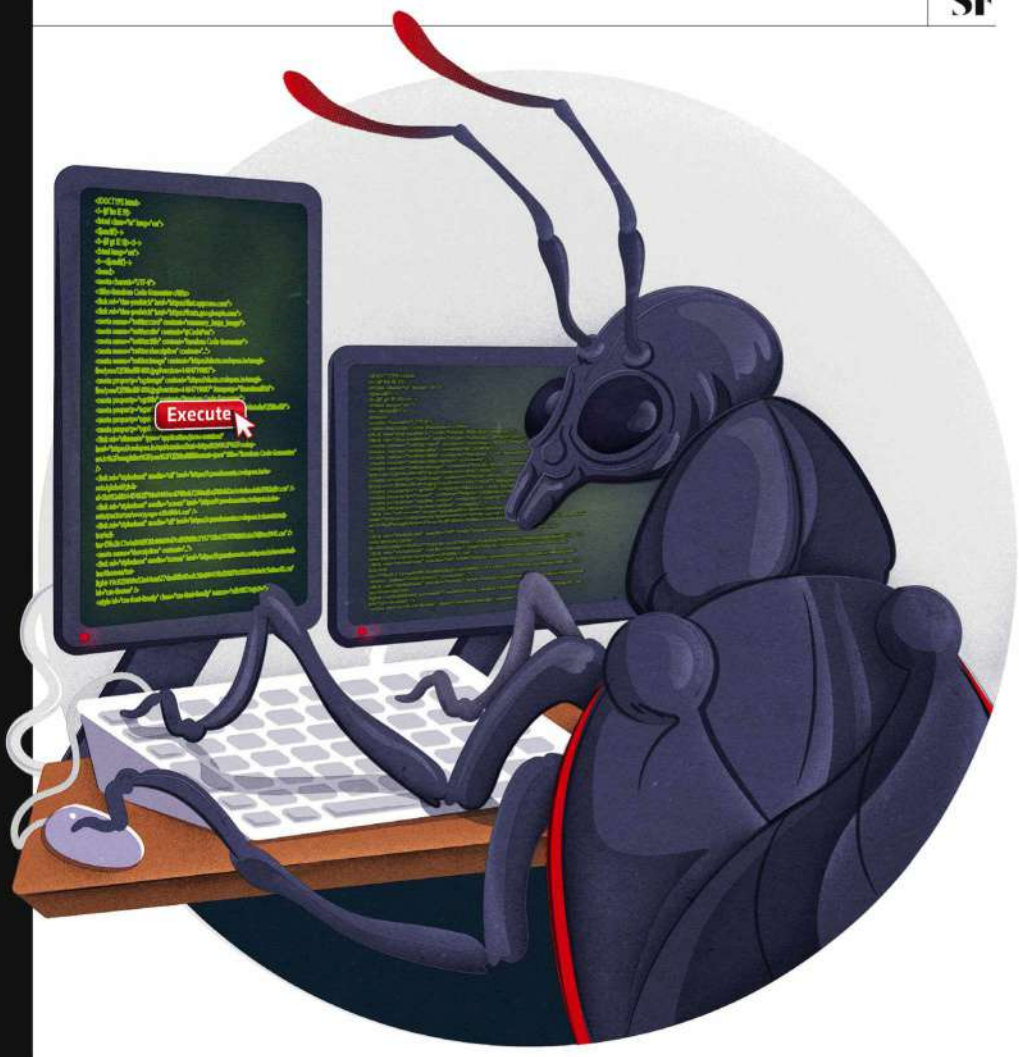


ILLUSTRATION: DANIEL BRIGHT

CHARLOTTE LEE, VIA EMAIL

HOW DO APPS AND COMPUTERS 'GET BUGS'?

We say that software has a bug or it's 'buggy' because it is malfunctioning. It's not working the way it is designed to work. This is usually the fault of a programmer somewhere, who either made a mistake or was not able to anticipate all the possible ways the software might operate. If you're the programmer who accidentally made things go wrong, it can be stressful, and the results can be far-reaching.

In 1962, the rocket carrying the Marina 1 space probe veered dangerously out of control and had to be destroyed 290 seconds after launch. The cause? A tiny bug in the guidance software (a missing hyphen in the code) which prevented it from receiving signals. The cost? $18m. In 2008, buggy software at the new Heathrow Terminal 5 resulted in thousands of bags being sent to the wrong locations and 500 flights cancelled at a cost of more than £16m.

And in the run up to the year 2000, the so-called 'millennium bug' resulted in costs of between $300bn and $500bn worldwide to prevent potential computer disasters. It was all because most software uses two digits rather than four to represent the year, so when the New Year arrived, the world's computers would suddenly think it was 1900 instead of 2000. That could have been a lot of timetables and schedules messed up.

It's the job of software testers to try and catch all the bugs, but when software is hugely complex and runs on thousands of different types of computer hardware in combination with millions of other pieces of software, it can be almost impossible to squash every last bug. All of which means that your unique computer setup with your specific software might just be that rare combination that makes the bug show itself – much to your frustration! ***PB***

NATURE'S WEIRDEST CREATURES...

HYRAX

The hyrax is a small, furry mammal that looks and behaves like things that it isn't. It looks like a rodent, but is more closely related to elephants and sea cows than it is to superficially similar pikas and marmots. Male hyraxes have no scrotum, and tuck their testicles up inside their abdominal cavities, just as male elephants do. Female hyraxes have three pairs of teats, including one pair near their armpits. Female elephants also have a pair of teats near their armpits. The diminutive herbivores, which live predominantly in Africa, also have tusks which develop from their incisor teeth, just like the tusks of elephants do.

Hyraxes dine on plants and have a three-chambered stomach that is laced with bacteria. It helps them to digest their food, and isn't a far cry from the four-chambered stomach of a cow. They are not good at maintaining their internal temperature, so they like to sunbathe during the day, just like a lizard. They live in small family groups, with a single male who defends their patch, which is easily spotted because hyraxes consistently urinate in the same place. Their urine is rich in calcium carbonate which stains the rocks white. Hyraceum, which is made of this petrified urine, is used in traditional South African medicine to treat epilepsy. *HP*

NOEL WALTERS, VIA EMAIL

WHEN YOU'RE HAVING A CAST REMOVED, WHY DOESN'T THE MACHINE CUT YOUR LIMB?

An orthopaedic cast is usually removed with a special cast saw, which is an oscillating power tool. While it might look like it could cause a lot of damage, a cast saw is designed with a sharp, small-toothed blade that rapidly oscillates back and forth over a very small angle to cut material. This is quite different to a normal circular saw, which has a rotating blade. A cast saw needs resistance to cut, and is specially designed to slice through rigid materials such as plaster. If it comes into contact with soft tissues such as skin, there is less resistance and so the saw will not cause injury. ***NM***

VICKY STEIN, VIA EMAIL

IS CHEWING GUM BIODEGRADABLE?

Globally, people chew roughly 100,000 tonnes of gum each year, but what happens once we've finished with it? Ancient civilisations chewed tree resins such as chicle, but by the 1950s this had been replaced by synthetic gums. Alongside this gum base, modern chewing gum contains softeners such as vegetable oil, emulsifiers that reduce stickiness, fillers like talc to add bulk, plus flavourings, sweeteners, preservatives and colourings. Synthetic gums are generally not biodegradable, but in some cases they can be recycled into new plastic products. New, more sustainable chewing gum alternatives use natural gums like tree sap or rubber. ***CA***

AIDEN CHAMBERS, LONDON

WHAT IS FREEZER BURN, AND SHOULD YOU STILL EAT THE FOOD?

You may have noticed that ice cubes kept in the freezer for a long time have a tendency to shrink as water is lost. This is because in dry freezer air, ice can transform directly into water vapour without first becoming a liquid, in a process known as sublimation. Ice sublimates in an effort to equilibrate with the vapour pressure of air in the freezer. The water lost from food items during sublimation is redeposited on the food's surface, and on refrigeration cools as ice crystals. The moisture loss means that fruit and vegetables can become shrivelled and dry, while meats can develop a leathery texture and dark spots. The dehydration creates pockets in the food which are then open to the air, accelerating oxidation. In fatty foods, this oxidation can cause unpleasant flavours. Food with freezer burn is unpalatable, but safe to eat.

All foods are susceptible to freezer burn, but those with higher moisture levels will develop it more rapidly. To reduce the likelihood of freezer burn, you can vacuum seal food to remove the air that drives the sublimation process. Or if you don't have a vacuum sealer, wrap the products as tightly as possible and stack them to limit the exposed surface area.

Finally, make sure you regularly rotate your freezer stock so that items are not left languishing for long periods. Some people suggest filling containers with water and leaving them open in the freezer to help maintain humidity and reduce sublimation. Self-defrosting freezers cause more burn. They regularly melt the ice layer on refrigeration coils, but this keeps the vapour pressure low, driving sublimation.

Freezer burn is similar to the freeze-drying process that food companies use to create long-life foods for astronauts and mountaineers, as well as instant coffee and some dried fruits. The industrial process involves freezing foods, dropping the pressure using a vacuum, then removing the ice. ***ED***

CHERYL-SAMANTHA OWEN/NATUREPL.COM, GETTY IMAGES X2, SHUTTERSTOCK ILLUSTRATION: DANIEL BRIGHT

DEAR DOCTOR...

HEALTH AND WELLBEING QUESTIONS DEALT WITH BY OUR EXPERTS

BILLY EVANS, NEWPORT

DOES THE BRAIN REALLY EXPERIENCE A 'GREAT RESTRUCTURING' AFTER WE TURN 40?

We know that the brain undergoes significant structural, functional and metabolic changes with age, with associated alterations in cognition and behaviour. A systematic review was recently published in the journal *Psychophysiology*, in which researchers from Australia looked at 144 studies and summarised how the connectivity of the human brain changes over our lifetimes.

They found that after the age of 40, the brain starts to undergo a rewiring that results in diverse networks becoming more integrated and connected. They suggest that this results in less flexible thinking, lower response inhibition, and reduced verbal and numeric reasoning.

While this may be compelling, it is worth noting that these types of studies are based on results from an imaging technique called functional MRI. These allow neuroscientists to observe the parts of subjects' brains that 'light up' in response to stimuli or when simply at rest. However, we can't really be sure that these are responsible for the changes in cognition that we see at the time – there might be a link, but it is difficult to prove. Looking at the data from the study, the 'restructuring' is fairly gradual, not a dramatic step-change each decade as might be suggested.

So maybe there is not a 'great restructuring', and we don't know exactly how this translates to cognition, but this review adds weight to the finding that there are changes in the brain that occur with ageing. *NM*

ALEX CARLSON, VIA EMAIL

WHAT WAS THE APPROXIMATE LIFESPAN OF A DINOSAUR?

It used to be thought that many dinosaurs achieved such huge sizes because they grew slowly and continuously, like crocodiles and iguanas do, for a century or more. We now know this wasn't the case, and that dinosaurs generally grew fast and died fairly young. We can tell the age of dinosaur fossils by cutting open their bones and counting growth lines; that's because, similar to a tree, dinosaurs laid down one ring of bone growth every year. This technique tells us that *Tyrannosaurus rex* reached full size in about 16 to 22 years, and usually died at 27 to 33 years old. Other big carnivores called Carcharodontosaurids lived to between 39 and 53 years old. The very largest dinosaurs, the long-necked sauropods like *Brontosaurus* and *Diplodocus,* seemed to have reached a similar age, although some could have lived maybe a decade or two longer – perhaps up to 70 years old. ***SB***

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

WHY IS GRIEF SO CRIPPLING?

Whether we're dealing with the death of a loved one, the pain of heartbreak or the end of a career, loss can feel unbearable. But grief is a natural part of life with deep roots in our evolutionary history.

Grief begins in the brain, but it affects the whole body. The moment we learn of our loss, our brain triggers the fight-or-flight response. This heightened state puts extra stress on our organs and bodily functions, and we would usually experience it for a few minutes to 48 hours. But after bereavement, the effects of the fight-or-flight response can continue for months. Even years later, being reminded of our loss can retrigger the response.

Though we've been led to believe grief has a trajectory of five stages – denial, anger, bargaining, depression and acceptance – it's really a non-linear process and its emotions can overlap, fade and reappear over time.

Psychologists believe these feelings associated with loss evolved when we started to survive by way of collaboration and community.

In the beginning, we yearn for what we've lost, which would've encouraged us to look for missing members of our group. Later, we become more ruminating, as our brain turns toward protecting us and our group against future losses.

In becoming a social species, we started to form deep, emotional attachments. By their very nature, these relationships have to be meaningful – to forgo the pain of grief, we'd also have to give up our ability to love. *AA*

GETTY IMAGES X3, ILLUSTRATION: PETE LAWRENCE

ASTRONOMY FOR BEGINNERS

Position of Venus and Jupiter relative to the horizon (approximately west-southwest) around 7pm

HOW TO SEE A BRIGHT CONJUNCTION

WHEN: LATE FEBRUARY AND EARLY MARCH

In popular parlance, 'conjunction' loosely describes when two or more objects appear close to one another in the night sky. There are several formal definitions of conjunction that describe when objects share the same coordinate values, but for general discussions, being 'close' is enough to qualify the term.

The planet Venus is now obvious in the post-sunset sky. A brilliant beacon, it's the brightest of all the planets visible from Earth. Jupiter is second brightest most of the time, except when Mars is brighter for short periods when near opposition. Late February provides an opportunity to spot both Venus and Jupiter as they appear to approach one another in the sky.

The action starts from 20 February, when Venus and Jupiter can be seen together above the west-southwest horizon after sunset. Start looking for them around 30 minutes after the Sun goes down, as visibility will become really obvious an hour after sunset. On this date, when you extend your arm in front of you, they appear to be a fist-width apart.

On 21 February, both planets will have moved slightly closer to one another and will be joined by a thin waxing crescent Moon. On 22 February, the Moon will sit between Venus and Jupiter – a lovely sight, given clear skies.

As the evenings progress, the Moon moves ever further eastward, and the planets get closer together. The closest approach occurs on 1 and 2 March. With both planets being so bright, if you have a phone with camera functionality, why not try and grab a snapshot of the pair?

As quickly as they approached one another, both planets will appear to separate again. Jupiter will slowly drift into the Sun's glare and be lost from view for a time, but Venus will continue to separate from the Sun to light up the spring evening sky. ***PL***

PAUL MCPHERSON, GLASGOW

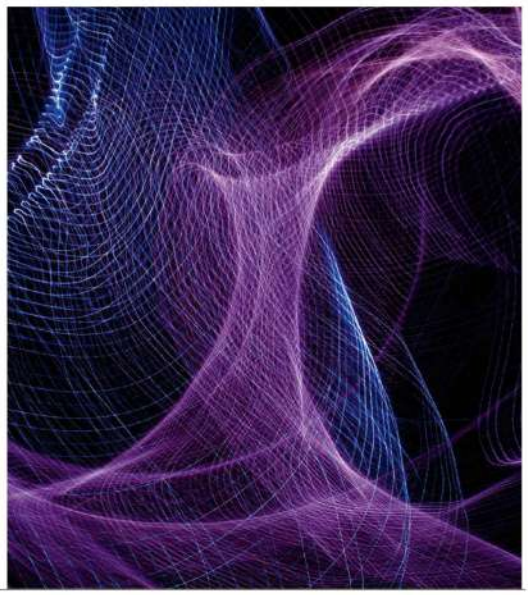
WHAT IS CHAOS THEORY?

Chaos theory is a branch of physics that describes the evolution of processes that are dependent on initial conditions. Some processes, which at first glance appear to be random, can in fact be based on underlying patterns and interdependencies. The classic example of a chaotic system is termed the 'butterfly effect', first highlighted by mathematician and meteorologist Edward Lorenz. Lorenz envisaged the apparent chaos of a tornado being dependent on a butterfly flapping its wings several weeks prior to the storm. Almost negligible changes in initial conditions can have dramatic and unpredictable effects on the evolution of a chaotic system.

There are several areas of astronomy that benefit from an understanding of chaos theory. The obvious one is the gravitational interaction of celestial bodies. Such a system is chaotic, and a tiny error in the positions or velocities of the celestial bodies, or the introduction of small perturbations, means the system is unpredictable in the long term.

Weather and climate here on Earth are good examples of chaotic systems. Similarly, features such as the Great Red Spot on Jupiter are also chaotic. Although scientists have a good grasp of fluid dynamics and the forces that result in this massive storm system, its formation and evolution cannot be predicted from these principles.

Most of the processes going on in the Universe are essentially chaotic. The acceleration of charged particles, the creation of cosmic rays, the structure of magnetic fields, nuclear reactions within stars, chemical reactions in interstellar space, and many more phenomena, are all critically dependent on initial conditions. Ultimately, it would be fair to say the Universe itself is chaotic and therefore unpredictable. ***AGu***



MYTHBUSTERS

COLLAGEN IN YOUR COFFEE: DOES IT ACTUALLY MAKE YOUR SKIN BETTER?

In the 1990s, everyone who watched *Friends* wanted Jennifer Aniston's haircut. Now, she's hoping that we'll all want to copy her morning cuppa: a coffee with a spoonful of her collagen supplement stirred in. But is there any scientific support for the claim that the supplement will "promote a youthful appearance"?

Collagen is one of the most abundant proteins in the body. It plays a role in building cells for skin, hair and nails, and as connective tissue in cartilage, muscle, and tendons. Studies have shown collagen's effectiveness in reducing symptoms of arthritis, repairing tendons and ligaments, and as a scaffold for growing tissues for testing in the laboratory.

The production of collagen is ramped up during childhood and puberty, but as we reach our late-20s, our ability to replenish collagen starts to decline. The main cells that synthesise collagen for the skin are called fibroblasts and they're sensitive to damage from sunlight and air pollution. The decline of collagen has been suggested as a main cause of wrinkles, with one study finding an 80-year-old's collagen production is decreased by 75 per cent compared with a young adult's.

So can collagen supplements stave off wrinkles, sagging skin and brown spots, as their sellers claim? Technically, collagen supplements – whether they're taken as pills, mixed up from a powder, or drunk as a hydrogel shot – contain a slightly different form of collagen to that made in our bodies. This is because pure collagen would be hard for us to digest. To put collagen into a supplement, it is therefore partially broken down in a process called hydrolysis. The result, hydrolysed collagen, can be consumed and digested safely.

But does it work? A review of 19 available studies, with a combined total of more than 1,000 participants, found that hydrolysed collagen supplements were effective in reducing the appearance of skin ageing, if taken for at least 90 days.

However, the same review cautioned that the individual studies could've been limited by their small numbers of participants. They also pointed out that these studies are often funded, at least in part, by the companies that manufacture the supplements. The authors conclude that claims by sellers, and their supporters, "surpass any evidence currently proven in the literature."

While some have said that the temperature of your beverage could diminish the benefits of collagen supplements, the limited amount of research available suggests you'd need much higher temperatures than that of your morning mocha – 150°C at least – to begin breaking down collagen into something unusable by your body. ***AA***

SAM DAWSON, VIA EMAIL

WHAT CAUSES A SONIC BOOM?

When an aircraft is flying below the speed of sound, sound waves ripple and spread out in front of and behind the plane. This contributes to the rumble and roar you hear when a plane is flying overhead. Of course, these waves are invisible, but we see something similar with slow-moving boats on calm water, when you can see gentle undulations of the bow and stern waves created by the boat's hull.

For the plane, the sound waves are spreading out from the aircraft at the speed of sound, which is about 1,200km/h (750mph). If the plane accelerates to the speed of sound or faster, then the sound waves can no longer move fast enough to get out of the way of the aircraft. The waves bunch up and combine to form a shock wave. This then trails behind the aircraft in a V-shape. Something similar is seen for the boat on water. When that craft speeds up and gets faster than the speed of the water waves, then V-shaped white water is seen trailing behind the boat.

For the aircraft, the shock wave is what causes the loud, thundering sonic boom. It's happening all the time, but for people on the ground, they only hear it once when the wake passes over them. Occasionally a double bang is heard, because two wakes are created, one by the aircraft nose and the other by the tail.

NASA is currently researching how to make a quieter sonic boom. They are doing this by shaping the supersonic aircraft so the wake created by the plane is less pronounced, meaning the boom is more muffled, making a 'whoomph' rather than a 'bang'. ***TC***

FAY BARRETT, CHESTER

WHY DO TEENS HAVE DIFFERENT SLEEP PATTERNS FROM ADULTS?

Our sleep changes throughout our lives in many different ways. When it comes to the amount of sleep that we need, this tends to decrease as we get older. Even though it may seem that teenagers need a lot of sleep, 14-year-olds to 17-year-olds typically need around 8 to 10 hours per night, which isn't too dissimilar to adults (7 to 9 hours per night).

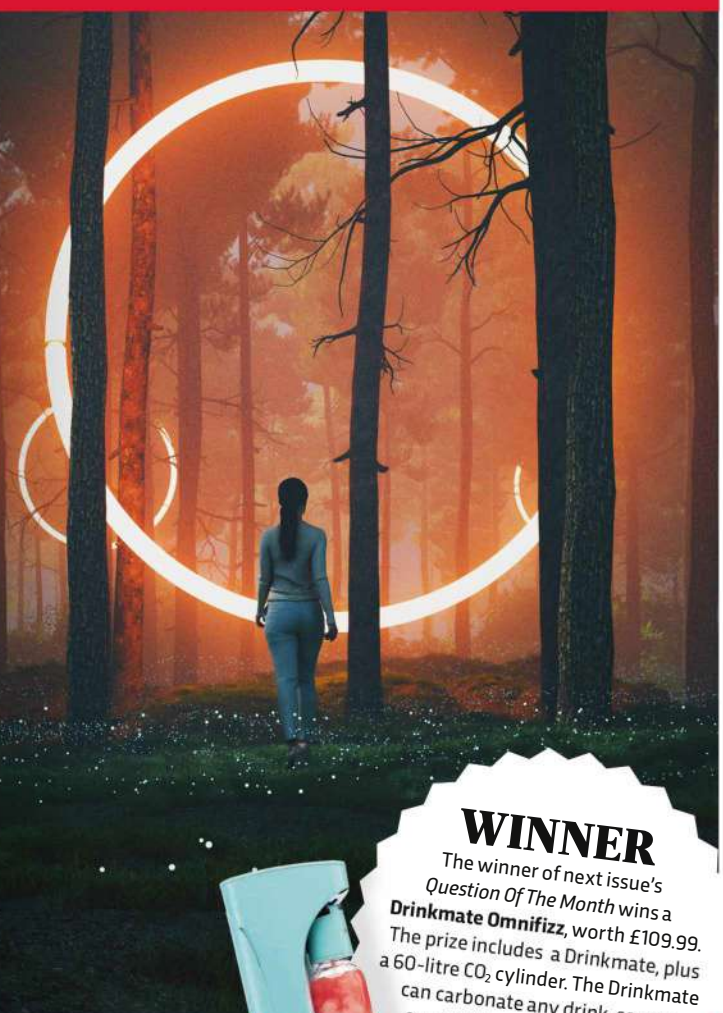
The timing of our sleep changes as we age. During adolescence, sleep timing becomes later, making an early bed and wake time tricky. Interestingly, this shift in sleep timing occurs in adolescents around the world and is even found in other mammals. Because society is geared towards early start times, young people often have to live out-of-sync with their natural patterns because they have to get up early to go to school in the week. If they are unable to fall asleep early, this can mean they miss out on sleep. When the weekend arrives, they have more control over their schedule, so fall asleep and wake up later. They may also attempt to 'catch up' on sleep lost during the school week.

This shift in sleep timing has been referred to as 'social jetlag', as a change in schedule can lead to jetlag-like symptoms. Social jetlag has been associated with factors including obesity and depression. So where does this leave young people who are confused as to whether they should attempt to get 'enough sleep' or stick to a consistent routine? It is sometimes recommended that a weekend lie-in is fine, but that ideally wake time should be within two hours of that during the working week, to allow some recovery from sleep deprivation, while limiting social jetlag. ***AGr***

QUESTION OF THE MONTH

WILLIAM WEBB, VIA EMAIL

AM I PSYCHIC?



The experience of turning around to find someone staring at you, almost as if you had 'felt' their stare, is common. Surveys suggest up to 90 per cent of us have had it. Research into the phenomenon goes back to the early days of scientific psychology at the end of the 19th Century. More recently, the 'sense of being stared at' has been studied extensively by parapsychology researchers such as Rupert Sheldrake (a believer) and Richard Wiseman (a sceptic).

Researchers like Sheldrake believe the effect is real and that we really can feel when someone is looking at us. In his experiments, Sheldrake found a tiny but statistically significant effect in support of the staring phenomenon – his volunteers could judge whether they were being stared at slightly better than if they had just guessed at random. But in similar studies, sceptical researchers such as Wiseman have turned up negative results. What's more, he and others have noted numerous problems with the studies conducted by 'believers'. For instance, issues with randomisation of the trials means that volunteers might have detected a pattern and used this to guide their judgments.

Rather than rewriting everything we know about the nature of the human mind and brain, there is a less exciting explanation for the sense of being stared at. It is that whenever we turn and find someone staring at us, we remember it, but all those times we turn and no one is looking, we don't. It's a similar story for feeling like you can predict when someone is about to text or call you – any time that you're thinking of someone and they ring, it feels uncanny, as though you foresaw the future. But more likely, it was just a coincidence, and you've probably forgotten all the times you were thinking of that person and they didn't get in touch. *CJ*

WINNER

The winner of next issue's *Question Of The Month* wins a **Drinkmate Omnifizz**, worth £109.99. The prize includes a Drinkmate, plus a 60-litre CO_2 cylinder. The Drinkmate can carbonate any drink, so you can add fizz to water, tea, juice and even cocktails.

drinkmate.uk

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

GETTY IMAGES X3 ILLUSTRATIONS: DANIEL BRIGHT

THE EXPLAINER

LUNAR PHOTOGRAPHY

TAKE DAZZLING IMAGES OF THE MOON, WHETHER YOU'RE A NEWBIE OR A PRO

PETE LAWRENCE/DIGITAL ASTRONOMY X4

BBC FOUR

Watch Pete on *The Sky At Night* on BBC Four, and catch up on iPlayer. Check *Radio Times* for details.

From craters and mountains, to valleys and frozen lava seas, there's a hidden world waiting to be captured if you point your camera towards the Moon. Since it's big, bright and easy to find, it is the perfect target with which to start your journey in astrophotography. Over the next few pages, we'll give you pointers to help you get the best from the Moon using a camera. We'll show you how to take great photos using just a smartphone and how to advance on to bigger equipment as you become more confident. A successful Moon-shot of your own may also give you the boost you need to point your camera further into the Solar System and deep space, so you can photograph the planets, stars and even spectacular deep-sky objects.

Beginner

Only got a smartphone? Perfect, you can still snap some great images of the Moon

The Moon is bright enough to photograph with a smartphone, but different makes and models will produce varying degrees of success. The Moon appears brightest when full and opposite the Sun in the sky. A rising full Moon looks artificially huge, due to an effect known as the 'Moon illusion'. A photo of this can be disappointing, with the Moon appearing much smaller than expected. If your camera favours the foreground, the Moon tends to overexpose. If your camera favours the Moon, the foreground can underexpose and become lost.

Try zooming in on the Moon's disc before you take your picture to record the dark and light regions on the Moon. Artificially intelligent assistants can augment images, producing detail which may not be real. For the best results, turn them off.

If you catch the Moon low, and the atmosphere is hazy or the sky not totally dark, it may be possible to record foreground detail and lunar disc features. It's a tough balance and something to aim for. Artistic shots, such as catching moonlight reflecting on water, can be interesting too.

While a bright full Moon may overexpose to look more like the Sun, a thin crescent Moon in the evening or morning sky, presented against the dusk or dawn twilight, may appear more 'Moon-like' in a photograph.

For more detailed images, 'afocal imaging' describes the technique of pointing a camera down the eyepiece of a telescope and can work surprisingly well. If you have access to a telescope, line up on the Moon and focus accurately, keeping glasses on if you wear them. Once done, point the camera down the eyepiece and press the shutter button. It's fiddly, but can produce impressive results.

Phone has favoured the foreground, making the Moon look overexposed

Phone has favoured the Moon, losing the foreground in the process

A smartphone photo of the Moon taken just after sunset, like this one, avoids the Moon overexposing, while keeping the foreground detail sharp

Intermediate

Once you've got a proper camera, you can start being more creative with your shots

A four-second exposure at ISO 800 of a crescent Moon brings out detail in the earthshine-lit lunar night. To the naked eye, the nightside (left) was barely visible next to the bright crescent (right)

A general photographic camera with interchangeable lenses opens the door to more detailed Moon images. The size of the Moon you'll capture in your image will depend on your lens's focal length. Anything over 200mm will begin to reveal tangible features on the Moon's surface. A 1,000mm focal length lens shows a very detailed full lunar disc.

If you can capture the Moon's shape, consider recording the daily change in phase, presenting the results in a calendar format. Be aware that the changing weather can get in the way of projects like this.

For the sharpest Moon detail, mount the camera on a platform such as a tripod. Use a remote shutter release to eliminate the need to physically press the shutter button, removing the risk of unwanted camera shake.

Set the camera and lens to manual. ISO settings should be low, say 200-1,600 for modern cameras. Lens aperture should be fully open with the caveat that some lenses show edge distortions under this setting. Selecting the lowest f-number (the f-number is the aperture, the lower the f-number, the more light the shutter lets in) and increasing by a stop or two should eliminate the distortion.

Accurate focus is essential. One trick is to turn the automatic focus (AF) on, and then half-press the shutter button with the Moon in view so the lens automatically focuses on the Moon's edge. Once done, switch the lens to manual focus (MF), being careful not to touch the focus ring again. The lens should now be correctly focused.

Plan to bracket exposures, using your camera's exposure meter as a base guide. Take a photo at the meter's recommended setting, along with longer and shorter exposures, checking each result on the camera's review screen.

A bright full Moon may appear tempting to photograph, but more dramatic views are found during the earlier and later phases, near where lunar day meets lunar night, a shadow line known as the 'terminator'. For early- or late-stage crescent moons, you can sometimes see the lunar nightside glowing because of sunlight reflecting off Earth; a phenomenon known as 'earthshine'. A longer exposure of a crescent Moon with earthshine will over-expose the bright portion but show lots of detail in the earthshine-lit portion.

The bright surface adjacent to the terminator is where sunlight is falling obliquely onto the Moon's surface. Here, features with height cast impressive shadows and intricate lunar details are presented at their dramatic best.

In the spring, the best time to photograph the crescent Moon is in the evening, because the Moon appears higher in the sky, setting at a steeper angle than in the autumn. In autumn, the reverse is true; crescents appear higher in the sky in the early morning. In astrophotography, higher altitude lifts subjects above the murky atmospheric layer close to the horizon.

At low altitude, the Moon's details will be blurred by Earth's atmosphere, but some interesting effects may be seen too. Here, as the Moon is starting to set, it is exhibiting a rare atmospheric phenomenon known as a red-flash

PETE LAWRENCE/DIGITAL ASTRONOMY X2, AN ECLIPSE FROM A THOUSAND SUNSETS BY NOAH KUJAWSKI/ROYAL OBSERVATORY GREENWICH ASTRONOMY PHOTOGRAPHER OF THE YEAR 14 COMPETITION

High frame rate techniques can be used to produce extremely detailed images of the Moon's surface

TOP TIPS

- Focus is important – take your time to get it spot on
- Take a shorter and longer exposure before and after what your camera suggests
- Surface detail is best at phases other than full Moon
- When attempting close-ups, a Moon that's high in the sky appears more stable than a lower one
- A remote shutter release avoids camera shake. On phones, pressing the volume control on a headphone lead may activate the shutter
- Barlow lenses and focal reducers can be used to adjust a telescope's effective focal length and image scale

Advanced

Got a telescope? Got a camera? Combine the two for expert-looking photos

More detailed images can be made by coupling an interchangeable lens camera – digital-single-lens-reflex (DSLR) or mirrorless-interchangeable-lens-camera (MILC) – to a telescope. Adapters for specific camera makes and models can be purchased from astronomy stockists. These consist of a ring with the correct camera fitting. Inside the ring there's a female T-thread; a de-facto standard used in astrophotography. A male T-threaded barrel screws into the adapter, the barrel sliding into the telescope's eyepiece holder. Telescopes tend to have either 1.25-inch or 2-inch barrels; modern ones are supplied with an interchangeable adapter for both sizes. Use the larger 2-inch size, if available.

Once coupled, the telescope is like a powerful telephoto lens of fixed f-number. Ideally, use low to mid ISO settings. Keeping exposures short will reduce effects caused by the apparent movement of the Moon arising from the rotation of Earth. Too long an exposure, and the Moon will show motion blur. A polar aligned, equatorial tracking mount will compensate for this motion, but isn't essential for short Moon exposures.

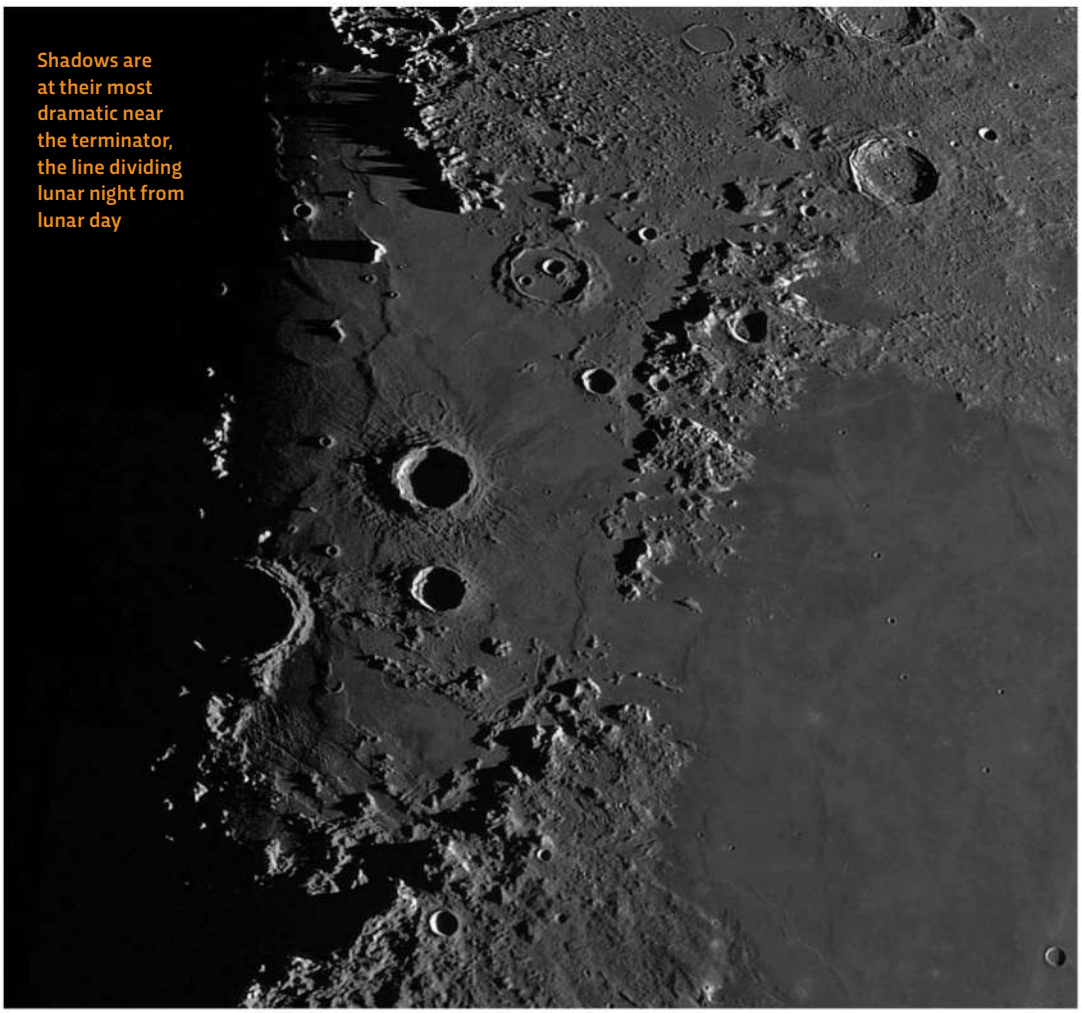
A highly magnified view of the Moon's surface appears to shimmer and wobble, due to something called 'atmospheric seeing'. This is a term describing micro-refraction of the Moon's light when it passes through Earth's turbulent atmosphere. In astronomical imaging, it distorts and blurs fine detail.

Atmospheric seeing effects are minimised using a technique known as 'lucky imaging'. This involves taking multiple short exposures, sorting the results by quality, aligning the best and averaging them together. This can be done with photographic cameras, but is more typically achieved using a high frame rate camera – essentially an industrial strength webcam. Dedicated to planetary, lunar and solar imaging, these devices typically capture hundreds, if not thousands, of frames over just a few seconds. The laborious task of processing the results can be automated with some freeware applications. Popular examples are Registax (**astronomie.be/registax**) and AutoStakkert (**autostakkert.com**). SF

"Short exposures will reduce effects caused by the apparent movement of the Moon arising from the rotation of Earth"

PETE LAWRENCE

Pete is an astronomer and photographer, who specialises in taking pictures of the Sun, Moon and planets. He is a presenter on BBC's The Sky At Night.



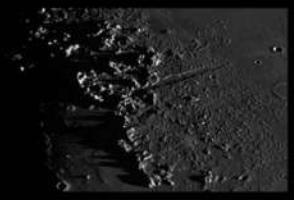
Shadows are at their most dramatic near the terminator, the line dividing lunar night from lunar day

PETE LAWRENCE/DIGITAL ASTRONOMY X11

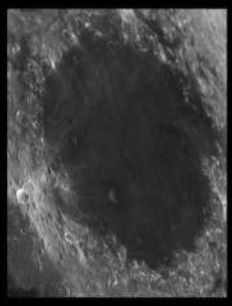
What to aim for

Here are some of the features you might spot while studying the Moon...

Mountains appear in huge ranges or as isolated peaks.



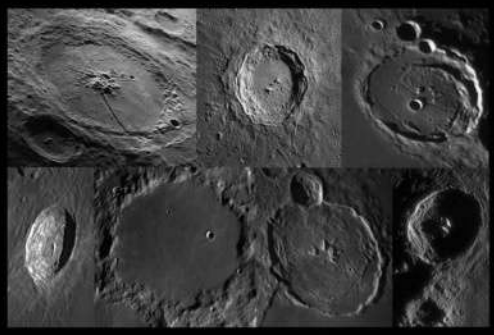
Valleys can be true geological features, or formed from chains of craters.



Seas (maria) are huge basins filled with dark, solidified lava.

Lunar highlands are the bright regions on the Moon's surface surrounding the lunar seas.

Craters are a result of impacts, and are visible in many different sizes.



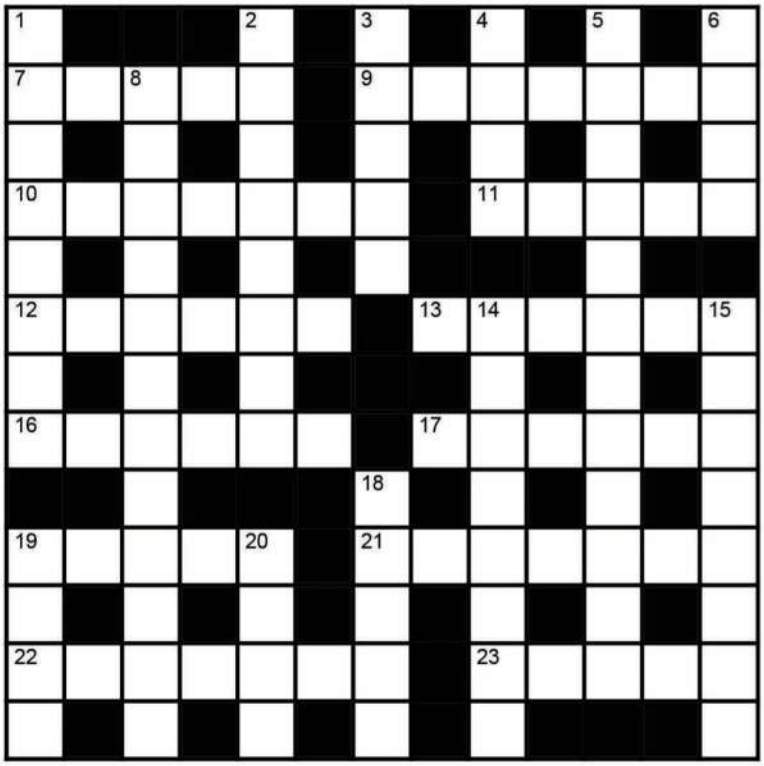
Rays appear as light streaks across the Moon. They are the result of material ejected from younger impact craters.

Craterlets are small craters that may appear within larger craters. The Clavius crater (pictured) has a series of craterlets that decrease in size.

The dividing line between lunar night and day is called the 'terminator'. The morning terminator is visible from new to full Moon (waxing phases), the evening terminator is visible from full to new Moon (waning phases).

CROSSWORD

PENCILS AT THE READY!



ACROSS

7 Attach a key with difficulty (5)
9 One church figure is found in cups (3,4)
10 Parasite broke my pearl (7)
11 Bored, I scout around a nightclub (5)
12 Firm with students – that is, a dog (6)
13 Batsman useful in the kitchen? (6)
16 Evaluate sketch show for an audience (6)
17 Draw everyone to Yorkshire river (6)
19 Permit uncultivated fellow to leave (5)
21 Associate new parent with resistance (7)
22 Adjusted cover around his first new military insignia (7)
23 Small, strangely airy land (5)

DOWN

1 Telegram about registered conveyance that's suspended (5-3)
2 Work out a problem (8)
3 Country giving left-wing politician variable answer (5)
4 Made drunk by a sweet concoction (4)
5 Nun burns beer, misused equipment (6,6)
6 Prize routinely hides nothing (4)
8 Standards of behaviour, relatively speaking? (6,6)
14 Divide capital, getting over large note (8)
15 Beer yard organised part of sandwich (3,5)
18 Betting in Spain shows courage (5)
19 Marched about building (4)
20 Threaten conflict to the north (4)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

SLIME

Hold your noses as we delve into the gruesome, gooey world of slime.

GETTY IMAGES

PLUS

HOW PROCESSED FOOD HARMS YOUR MOOD

Psychologist and nutritionist Kimberley Wilson reveals all.

AMAZON RAINFOREST

Why is it so vital to life on Earth?

ON SALE 16 MARCH

SF

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POPCORN SCIENCE

Could humans shrink themselves?

Ant-Man is back again, so let's find out if a superhero who can bend the laws of physics is realistic...

by **STEPHEN KELLY**

It's a tiny bird! It's a miniature plane! It's Ant-Man! Yes, the bite-sized superhero is back in the new film *Ant-Man And The Wasp: Quantumania*, where he is set to shrink to the size of particles.

The idea of shrinking people is a popular one in science fiction – just take *Fantastic Voyage* or *Honey, I Shrunk The Kids* – but is it feasible in reality? James Kakalios, a physics professor at the University of Minnesota, and author of *The Physics Of Superheroes*, is not convinced.

"My first thought is: I wish. My second thought is: no," he says. "The size of atoms is determined by quantum mechanics and electrostatics, which involve a set of fundamental constants and fundamental interactions. Constants are constant; they don't change. Without being able to change those constants, and without being able to change the nature of the electrostatic interaction, there's no way to reduce the size of an atom."

Well, that's not right, because Dr Hank Pym – the original Ant-Man, played by Michael Douglas in the films – has not only figured out how to shrink Scott Lang (Paul Rudd) to the size of an ant, but also how to retain his full-sized strength while remaining lightweight.

"If you have the mass of an ant, you are not knocking down a bad guy," says Kakalios, who theorises that Pym would have had to figure out a way for Lang to change his mass at will during a fight. "When he sits on an ant, he doesn't smush it in the same way I would," he says. "This makes me think that Pym can manipulate the Higgs field, the thing that gives all matter the mass and inertia that it has. So, only two impossible things! What a genius!"

Without such an innovation, Lang would struggle to punch his way out of a paper bag. But if Pym had indeed figured out how to increase a tiny Lang's mass at the same time as he is throwing a punch, it could make him deadly. "He would have to be careful," says Kakalios. "You could punch a small hole in their neck and pierce the jugular vein. It would be like being struck with a bullet."

Speaking of which, there is a popular fan theory floating around the internet that Ant-Man is perhaps the most powerful Avenger of all; that it is he, and only he, that has the power to kill Thanos and stop all the events of *Infinity War* and *Endgame* from happening. All he would have to do is to shrink down to the size of an ant, climb inside Thanos from a certain orifice, and then blow up to full-size, theoretically destroying Thanos in the process.

What does James Kakalios, a distinguished professor, think of that theory? "Oh god," he says. "You're talking about Thanos' butt!" Yep, that's exactly what we're talking about. "What I will say is that Thanos is very strong, possibly inside and out. Say that Scott, initially the size of an ant, expands in a room that is surrounded by miles thick concrete walls in all directions – all he's going to do is crack his own skull."

So what you're saying, James, is that Thanos could have bowels of steel?

"You know," he says, "I'd say this is one case where I'm willing to take my science hat off and say: I don't need experimental verification." **SF**

VERDICT

Sadly, in the real world, it is just not possible to break the laws of physics, which means superheroes need to stay boringly human-sized.

by **STEPHEN KELLY** *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

ILLUSTRATION: JOE WALDRON

This was Sylvia's promise to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

She kept her promise, and a gift to the Stroke Association was included in her Will. Sylvia's gift helped fund the work that made sure many more of us survive stroke now than did in her lifetime.

Sylvia changed the story for us all. Now it's our turn to change the story for those who'll come after us.

Stroke still shatters lives and tears families apart. And for so many survivors the road to recovery is still long and desperately lonely. If you or someone you love has been affected by stroke – you'll know just what that means.

But it doesn't have to be like this. You can change the story, just like Sylvia did, with a gift in your Will. All it takes is a promise.

You can promise future generations a world where researchers discover new treatments and surgeries and every single stroke survivor has the best care, rehabilitation and support network possible, to help them rebuild their lives.

Will you make that promise to generations to come? Please, leave a gift in your Will to the Stroke Association.

Find out how by calling 020 7566 1505
or email legacy@stroke.org.uk
or visit stroke.org.uk/legacy

Rebuilding lives after stroke

The Stroke Association is registered as a charity in England and Wales (No 211015) and in Scotland (SC037789).
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Stroke Association

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